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Society
FOR THE
Promotion of Engineering Education.

PROCEEDINGS
OF THE
SEVENTH ANNUAL MEETING,
HELD IN
COLUMBUS, OHIO, AUGUST 17, 18, 19, 1899.

Volume VII.

EDITED BY
THOS. C. MENDENHALL, IRA O. BAKER, ALBERT KINGSBURY,
EDGAR MARBURG,
Committee.

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1899-1900.

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J. Madison Porter, Lafayette College,
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* This list gives only the elective members. The officers (p. v) and the past presidents (p. xxiv) are members of the Council *ex officiis*.

LIST OF MEMBERS.

NAME AND ADDRESS.	TITLE.	DATE OF MEMBERSHIP.
ADAMS, COMFORT A., JR. Cambridge, Mass.	Assistant Professor of Electrical Engineering, Harvard University	1894
ALDRICH, WILLIAM S. Urbana, Ill.	Professor of Electrical Engineering, University of Illinois	1893
ALLEN, C. FRANK Boston, Mass.	Professor of Railroad Engineering, Massachusetts Institute of Technology	1893
ANDERSON, F. PAUL Lexington, Ky.	Dean of School of Mechanical and Electrical Engineering, Professor of Mechanical Engineering	1894
ANTHONY, GARDNER C. Tufts College, Mass.	Professor of Technical Drawing, Tufts College	1896
ARNOLD, BION J. Chicago, Ill.	Consulting Electrical Engineer	1896
AYER, ARTHUR W. Burlington, Vt.	Professor of Mechanical Engineering, University of Vermont	1894
AYRES, BROWN New Orleans, La.	Professor of Physics and Electrical Engineering, Dean of College of Technology, Tulane University	1898
BAKER, IRA O. Champaign, Ill.	Professor of Civil Engineering, University of Illinois	1893
BALDWIN, WARD Cincinnati, Ohio.	Professor of Civil Engineering, University of Cincinnati	1893
BARBOUR, VOLNEY G. Burlington, Vt.	Professor of Mechanics and Bridge Engineering, Dean of Engineering Department, University of Vermont	1894
BARNEY, SAMUEL E., JR. New Haven, Conn.	Assistant Professor of Civil Engineering, Yale University	1894
BENDING, EDWARD A. Dayton, Ohio.	Principal Dayton Manual Training School.	1899
BENJAMIN, CHARLES H. Cleveland, Ohio.	Professor of Mechanical Engineering, Case School of Applied Science	1893

Name and Address.	Title.	Date of Membership.
Beyer, Samuel W. Ames, Iowa.	Professor of Geology and Mining Engineering, Iowa State Agricultural College	1899
Beyer, T. Raymond 119 Maplewood Ave., Germantown, Pa.	Civil Engineer	1895
Bissell, George W. Ames, Iowa.	Professor of Mechanical Engineering, Iowa State Agricultural College	1894
Bixby, Wm. H. Cincinnati, Ohio.	Major Corps of Engineers, U. S. Army, U. S. Engineer Office	1898
Bohannan, Rosser D. Columbus, Ohio.	Professor of Mathematics, Ohio State University	1899
Bovey, Henry T. Montreal, Que.	Professor of Civil Engineering and Applied Mechanics, McGill University	1893
Bradford, Joseph N. Columbus, Ohio.	Associate Professor of Drawing, Ohio State University	1896
Brady, Frank W. Mesilla Park, New Mex.	Professor of Engineering, College of Agriculture and the Mechanic Arts	1899
Bray, Charles D. Tufts College, Mass.	Professor of Civil and Mechanical Engineering, Tufts College	1894
Breckenridge, Lester P. Urbana, Ill.	Professor of Mechanical Engineering, University of Illinois	1893
Brill, George M. Chicago, Ill.	Supervising Engineer, Swift & Co.	1894
Brooks, John P. Lexington, Ky.	Professor of Civil Engineering, State College of Kentucky	1898
Brooks, Morgan Lincoln, Neb.	Professor of Electrical Engineering, University of Nebraska	1899
Brown, Charles C. Bloomington, Ill.	Consulting Engineer	1894
Browne, Wm. H., Jr. Urbana, Ill.	Assistant Professor of Electrical Engineering, University of Illinois	1899
Bull, Storm Madison, Wis.	Professor of Steam Engineering, University of Wisconsin	1893
Bunte, Hans Karlsruhe, Germany.	Aulic Counselor, Professor in the Polytechnic, Director of the Institute of Chemistry and Technology and of the Grand-Ducal Experiment Station	1893

Name and Address.	Title.	Date of Membership.
BURGESS, CHARLES F. Madison, Wis.	Instructor in Electrical Engineering, University of Wisconsin	1896
BURNHAM, ALTON C.		1896
BURNHAM, EDWARD C. Providence, R. I.	Associate Professor of Mechanical Engineering, Brown University	1899
BURR, WILLIAM H. New York, N. Y.	Professor of Civil Engineering, Columbia University	1893
BURRAGE, SEVERANCE Lafayette, Ind.	Instructor in Sanitary Science, Purdue University	1898
BURTON, ALFRED E. Boston, Mass.	Professor of Topographical Engineering, Massachusetts Institute of Technology	1893
CALDWELL, FRANCIS C Columbus, Ohio.	Associate Professor of Electrical Engineering, Ohio State University	1897
CARPENTER, LOUIS G. Fort Collins, Colo.	Professor of Civil and Irrigation Engineering, Director of Experiment Station, Colorado State Agricultural College	1895
CARPENTER, ROLLA C Ithaca, N. Y.	Professor of Experimental Engineering, Cornell University	1893
CARSON, WILLIAM W. Knoxville, Tenn.	Professor of Civil Engineering, University of Tennessee	1894
CHATBURN, GEORGE R. Lincoln, Neb.	Adjunct Professor of Civil Engineering, University of Nebraska	1899
CHAUVENET, REGIS Golden, Colo.	President, State School of Mines of Colorado	1896
CHRISTY, SAMUEL B. Berkeley, Cal.	Professor of Mining and Metallurgy, University of California	1893
CONSTANT, FRANK H. Minneapolis, Minn.	Professor of Structural Engineering, University of Minnesota	1896
COOLEY, MORTIMER E. Ann Arbor, Mich.	Professor of Mechanical Engineering, University of Michigan	1893
CORTHELL, ELMER L. 27 Pine St., New York.	Civil Engineer	1895
CORY, HARRY T. Columbia, Mo.	Professor of Civil Engineering, Missouri State University	1895

NAME AND ADDRESS.	TITLE.	DATE OF MEMBERSHIP.
CRAFTS, JAMES M. Boston, Mass.	President, Massachusetts Institute of Technology	1898
CRANDALL, CHARLES L. Ithaca, N. Y.	Professor of Civil Engineering, Cornell University	1893
CREIGHTON, W. H. P. New Orleans, La.	Professor of Mechanical Engineering, Tulane University	1893
CRENSHAW, BOLLING H. Auburn, Ala.	Professor of Mathematics and Mechanical Engineering, Alabama Polytechnic Institute	1894
CROSS, CHARLES R. Boston, Mass.	Professor of Physics, Massachusetts Institute of Technology	1895
CRUIKSHANK, BARTON Potsdam, N. Y.	President, Clarkson School of Technology	1899
DANIELS, FRANK T. Tufts College, Mass.	Instructor in Civil Engineering Tufts College	1896
DE BRAY, M. Paris, France.	Professor, Ecôle des Ponts et Chaussées	1893
DENISON, CHARLES S. Ann Arbor, Mich.	Professor of Descriptive Geometry, Stereotomy and Drawing, University of Michigan	1893
DENTON, JAMES E. Hoboken, N. J.	Professor of Experimental Mechanics, and Superintendent of Tests, Stevens Institute of Technology	1893
DENTON, FREDERICK W. Houghton, Mich.	Superintendent, Winona Mine	1894
DROWN, THOMAS M. South Bethlehem, Pa.	President, Lehigh University	1895
DU BOIS, A. JAY New Haven, Conn.	Professor of Civil Engineering, Yale University	1894
DUDLEY, CHARLES B. Altoona, Pa.	Chemist, Pennsylvania Railroad Company	1894
DURAND, WILLIAM F. Ithaca, N. Y.	Professor of Marine Engineering, Cornell University	1899
EDDY, HENRY T. Minneapolis, Minn.	Professor of Engineering and Mechanics, University of Minnesota	1893
EMORY, FREDERICK L. Morgantown, W. Va.	Professor of Mechanics and Applied Mathematics, West Virginia University	1894

Name and Address.	Title.	Date of Membership.
Engler, Edmund A. St. Louis, Mo.	Professor of Mathematics, Dean of Engineering School, Washington University	1897
Esty, William Urbana, Ill.	Associate Professor of Electrical Engineering, University of Illinois	1898
Faig, John T. Lexington, Ky.	Assistant Professor of Mechanical Engineering, Kentucky Agricultural and Mechanical College	1899
Farwell, Elmer S. 30 Broad St., New York.	Steam Engineer, International Paper Co	1895
Fernald, Robert H. Cleveland, O.	Assistant Professor of Mechanical Engineering, Case School of Applied Science	1899
Fisher, James, Jr. Houghton, Mich.	Instructor in Mathematics and Physics, Michigan College of Mines	1899
Flather, John J. Minneapolis, Minn.	Professor of Mechanical Engineering, University of Minnesota	1893
Fletcher, Robert Hanover, N. H.	Professor of Civil Engineering, Director of Thayer School, Dartmouth College	1894
Flint, Walter Orono, Me.	Professor of Mechanical Engineering, University of Maine	1898
Forth, Francis C. Manchester, Eng.	Assistant Director, Municipal Technical School	1898
Foss, Fred. E. State College, Pa.	Professor of Civil Engineering, Pennsylvania State College	1893
French, Thomas E. Columbus, O.	Assistant Professor of Drawing, Ohio State University	1899
Fuertes, Estevan A. Ithaca, N. Y.	Director and Dean of College of Civil Engineering, Cornell University	1894
Fullan, M. Thomas J. Auburn, Ala.	Assistant in Mechanical Engineering, Alabama Polytechnic Institute	1897
Fulton, Henry Boulder, Colo.	Professor of Civil Engineering, University of Colorado	1894
Galbraith, John Toronto, Ont.	Principal and Professor of Engineering, School of Practical Science	1893

Name and Address.	Title.	Date of Membership.
Geer, Herbert G. 317 Equitable Building, Baltimore. Md.	Consulting Electrical and Mechanical Engineer	1894
Giesecke, F. E. College Station, Tex.	Professor of Drawing, Texas Agricultural and Mechanical College	1893
Gill, James H. Minneapolis, Minn.	Instructor in Machine and Tool Construction, University of Minnesota	1896
Goldsborough, Winder E. Lafayette, Ind.	Professor of Electrical Engineering, Director of the Electrical Laboratory, Purdue University	1897
Goodman, John Leeds, England.	Professor of Engineering, Yorkshire College, Victoria University	1893
Goss, William F. M. Lafayette, Ind.	Professor of Experimental Engineering, Director of Engineering Laboratories, Purdue University.	1893
Gray, Thomas Terre Haute, Ind.	Professor of Dynamic Engineering, Rose Polytechnic Institute	1895
Groat, Benjamin F. Minneapolis, Minn.	Instructor in Mechanics, University of Minnesota	1899
Grover, Nathan C. Orono, Me.	Professor of Civil Engineering, University of Maine	1894
Hall, Christopher W. Minneapolis, Minn.	Professor of Geology and Mineralogy, University of Minnesota	1894
Halsted, George B. Austin, Tex.	Professor of Mathematics, University of Texas	1899
Hamlin, George H. Orono, Me.	Civil Engineer	1895
Hampson, William B. Lincoln, Neb.	Instructor in Mechanical Engineering, University of Nebraska	1896
Harper, Joseph D. Manhattan, Kan.	Professor of Engineering, Director of Shops, Kansas State Agricultural College	1899
Harris, Abram W. Orono, Me.	President, University of Maine	1897
Harris, Elmo G. Rolla, Mo.	Professor of Engineering, Missouri School of Mines	1894

Name and Address.	Title.	Date of Membership.
Hatt, William K Lafayette, Ind.	Associate Professor of Applied Mechanics, Purdue University	1895
Haynes, Arthur E Minneapolis, Minn.	Professor of Mathematics, University of Minnesota	1895
Hazen, John V Hanover, N. H.	Professor of Civil Engineering, Dartmouth College	1896
Hibbard, H. Wade Ithaca, N. Y.	Principal of the Graduate School of Railway Mechanical Engineering, Sibley College, Cornell University	1896
Hill, John E Providence, R. I.	Associate Professor of Civil Engineering, Brown University	1894
Hitchcock, Embury A Columbus, Ohio.	Associate Professor of Experimental Engineering, Ohio State University	1899
Hoag, William R Minneapolis, Minn.	Professor of Civil Engineering, University of Minnesota	1893
Hofman, Heinrich O Boston, Mass.	Professor of Metallurgy, Massachusetts Institute of Technology	1894
Hollis, Ira N Cambridge, Mass.	Professor of Engineering, Harvard University	1894
Hood, Ozni P Houghton, Mich.	Professor of Mechanical and Electrical Engineering, Michigan College of Mines	1893
Hoskins, Leander M Stanford University, Cal.	Professor of Applied Mechanics, Leland Stanford Junior University	1893
Howe, Malverd A Terre Haute, Ind.	Professor of Civil Engineering, Rose Polytechnic Institute	1894
Hume, Alfred University, Miss.	Professor of Mathematics, University of Mississippi	1894
Humphreys, David C Lexington, Va.	Professor of Civil Engineering, Washington and Lee University	1893
Hutton, Frederick R New York, N. Y.	Professor of Mechanical Engineering, Columbia University	1894
Jackson, Dugald C Madison, Wis.	Professor of Electrical Engineering, University of Wisconsin	1893
Jackson, John P State College, Pa.	Professor of Electrical Engineering, Pennsylvania State College	1894

NAME AND ADDRESS.	TITLE.	DATE OF MEMBERSHIP.
JACOBUS, D. S. Hoboken, N. J.	Professor of Experimental Mechanics and Engineering Physics, Stevens Institute of Technology	1893
JACOBY, HENRY S. Ithaca, N. Y.	Associate Professor of Bridge Engineering and Graphics, Cornell University.	1894
JOHNSON, JOHN B. Madison, Wis.	Dean of College of Mechanics and Engineering, University of Wisconsin.	1893
JOHNSON, LEWIS J. Cambridge, Mass.	Assistant Professor of Civil Engineering, Lawrence Scientific School, Harvard University	1898
JONES, CLEMENT R. Morgantown, W. Va.	Assistant Professor of Mechanical Engineering, West Virginia University.	1895
JONES, FORREST R. Madison, Wis.	Professor of Machine Design, Worcester Polytechnic Institute	1893
KAY, EDGAR B. Ithaca, N. Y.	Instructor in Civil Engineering, Cornell University,	1898
KENT, WILLIAM Passaic, N. J.	Consulting Engineer, Associate Editor of 'Engineering News,' New York City	1894
KIDWELL, EDGAR Hancock, Mich.	Superintendent, Arcadian Copper Mining Company	1896
KIMBALL, RODNEY G. Brooklyn, N. Y.	Professor of Applied Mathematics. The Polytechnic Institute of Brooklyn	1894
KINEALY, J. H. St. Louis, Mo.	Professor of Mechanical Engineering, Washington University	1893
KINGSBURY, ALBERT Worcester, Mass.	Professor of Applied Mechanics, Worcester Polytechnic Institute	1893
KNOCH, JULIUS J. Fayetteville, Ark.	Professor of Civil Engineering, University of Arkansas	1898
KYSER, HENRY H. Auburn, Ala.	Instructor in Physics, Director of Physical Laboratory, Alabama Polytechnic Institute	1897
LAMBERT, PRESTON A. South Bethlehem, Pa.	Assistant Professor of Mathematics, Lehigh University	1897
LANDRETH, OLIN H. Schenectady, N. Y.	Professor of Civil Engineering, Union College	1893

NAME AND ADDRESS.	TITLE.	DATE OF MEMBERSHIP.
LANPHEAR, BURTON S. 30 Broad St., New York.	With International Paper Company, Department of Construction and Maintenance	1897
LANZA, GAETANO Boston, Mass.	Professor of Applied Mechanics in charge of the Department of Mechanical Engineering, Massachusetts Institute of Technology	1893
LA RUE, BENJAMIN F. Scranton, Pa.	Principal School of Civil Engineering, International Correspondence Schools	1899
LAWRENCE, JAMES W. Fort Collins, Colo.	Professor of Mechanical Engineering, State Agricultural College	1898
LORD, NATHANIEL W. Columbus, O.	Professor of Metallurgy and Mineralogy, Ohio State University	1899
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McCOLL, JAY R. Knoxville, Tenn.	Professor of Mechanical Engineering, University of Tennessee	1894
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McNAIR, FREDERICK W. Houghton, Mich.	President, Michigan College of Mines	1897
MAGOWAN, CHARLES S. Iowa City, Iowa.	Assistant Professor of Civil Engineering, State University of Iowa	1896
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MARBURG, EDGAR Philadelphia, Pa.	Professor of Civil Engineering, University of Pennsylvania	1894
MARSTON, ANSON Ames, Iowa.	Professor of Civil Engineering, Iowa State Agricultural College	1894
MARVIN, FRANK O. Lawrence, Kan.	Dean of the School of Engineering, Professor of Civil Engineering, University of Kansas	1893

NAME AND ADDRESS.	TITLE.	DATE OF MEMBERSHIP.
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MATHER, THOMAS W. New Haven, Conn.	Principal Boardman Manual Training High School	1894
MATHEWS, HUBERT B. Brookings, S. Dak.	Professor of Physics, South Dakota Agricultural College	1896
MATTHEWS, CHARLES P. Lafayette, Ind.	Associate Professor of Electrical Engineering, Purdue University.	1898
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MENDENHALL, THOMAS C. Worcester, Mass.	President, Worcester Polytechnic Institute	1895
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MORLEY, FREDERICK Lafayette, Ind.	Professor of Civil Engineering, Purdue University	1896
MUNROE, HENRY S. New York, N. Y.	Professor of Mining, Columbia University	1893
NAGLE, JAMES C. College Station, Tex.	Professor of Civil Engineering, Agricultural and Mechanical College of Texas	1897
NEFF, FRANK H. Cleveland, Ohio.	Professor of Civil Engineering, Case School of Applied Science	1895
ORDWAY, JOHN M. New Orleans, La.	Professor of Applied Chemistry, Acting Professor of Civil Engineering, Tulane University	1894
OSTRANDER, JOHN E. Amherst, Mass.	Professor of Mathematics and Civil Engineering, Massachusetts Agricultural College	1894
OWENS, ROBERT B. Montreal, Que.	Professor of Electrical Engineering, McGill University	1894
PALMER, WALTER K. Lawrence, Kan.	Associate Professor of Mechanical Engineering, Kansas State University	1899

NAME AND ADDRESS.	TITLE.	DATE OF MEMBERSHIP.
PATTERSON, GEORGE W., JR. Ann Arbor, Mich.	Junior Professor of Physics, University of Michigan	1896
PEABODY, CECIL H. Boston, Mass.	Professor of Marine Engineering and Naval Architecture, Massachusetts Institute of Technology	1894
PENCE, WILLIAM D. Lafayette, Ind.	Professor of Civil Engineering, Purdue University	1895
PETTEE, CHARLES H. Durham, N. H.	Professor of Mathematics, New Hampshire College	1898
PHILLIPS, JAMES D. Champaign, Ill.	Assistant Professor of Engineering Drawing, University of Illinois	1899
PORTER, DWIGHT Boston, Mass.	Professor of Hydraulic Engineering, Massachusetts Institute of Technology	1893
PORTER, J. MADISON Easton, Pa.	Professor of Civil Engineering, Lafayette College	1893
PUPIN, MICHAEL I. New York, N. Y.	Adjunct Professor of Mechanics, Columbia University	1895
RANDOLPH, LINGAN S. Blacksburg, Va.	Professor of Mechanical Engineering, Virginia Polytechnic Institute	1894
RAYMOND, WILLIAM G. Troy, N. Y.	Professor of Geodesy and Road Engineering, Rensselaer Polytechnic Institute	1893
REBER, LOUIS E. State College, Pa.	Professor of Mechanical Engineering, Pennsylvania State College	1893
RICE, ARTHUR L. Brooklyn, N. Y.	Professor of Steam Engineering and Applied Electricity, Pratt Institute	1894
RICHARDS, CHARLES R. Lincoln, Neb.	Professor of Practical Mechanics, Director of the School of Mechanic Arts, University of Nebraska	1895
RICHARDS, ROBERT H. Boston, Mass.	Professor of Mining Engineering and Metallurgy, Massachusetts Institute of Technology	1895
RICHTER, ARTHUR W. MADISON, Wis.	Assistant Professor of Steam Engineering, University of Wisconsin	1894
RICKER, NATHAN C. Urbana, Ill.	Dean of College of Engineering, University of Illinois	1894

Name and Address.	Title.	Date of Membership.
Ricketts, Palmer C. Troy, N. Y.	Director, Rensselaer Polytechnic Institute	1893
Riggs, Walter M. Clemson College, S. C.	Instructor in Electrical Engineering, in charge of Electrical Laboratories, Clemson Agricultural College	1897
Ripper, William. Sheffield, Eng.	Professor of Engineering, University College	1893
Ritter, C. Wilhelm Zurich, Switzerland.	Professor of Civil Engineering, Federal Swiss Polytechnic	1893
Robbins, Arthur G. Boston, Mass.	Assistant Professor of Highway Engineering, Massachusetts Institute of Technology	1894
Robinson, Edward Potsdam, N. Y.	Professor of Mechanical Engineering, Clarkson School of Technology	1899
Robinson, Frederic H. Newark, Del.	Professor of Civil Engineering, Delaware College	1894
Robinson, Stillman W. 1353 Highland Street, Columbus, Ohio.	Mechanical Engineer and Expert	1893
Rosebrugh, Thomas R. Toronto, Ontario.	Lecturer in Electrical Engineering, School of Practical Science	1896
Sackett, Robert L. Richmond, Ind.	Professor of Applied Mathematics and Astronomy, Earlham College	1893
Sanborn, Frank E. Columbus, O.	Director Industrial Arts Department, Ohio State University	1899
Schmidt, Edward C. Urbana, Ill.	Instructor in Mechanical Engineering, University of Illinois	1899
Schuerman, William H. Nashville, Tenn.	Dean of the Engineering Department, Professor of Civil Engineering, Vanderbilt University	1895
Sedgwick, William T. Boston, Mass.	Professor of Biology, Massachusetts Institute of Technology	1896
Shepardson, George D. Minneapolis, Minn.	Professor of Electrical Engineering, University of Minnesota	1895
Smart, Richard A. Lafayette, Ind.	Associate Professor of Experimental Engineering, Purdue University	1896
Smith, Harold B. Worcester, Mass.	Professor of Electrical Engineering, Worcester Polytechnic Institute	1898

NAME AND ADDRESS.	TITLE.	DATE OF MEMBERSHIP.
SMITH, HARRY E. Minneapolis, Minn.	Assistant Professor of Mechanical Engineering, University of Minnesota	1895
SMITH, HERBERT S. S. Princeton, N. J.	Professor of Applied Mechanics, Princeton University	1894
SNOW, CHARLES H. New York, N. Y.	Dean of School of Applied Science, New York University	1895
SNOW, WALTER B. 29 Russell Ave., Watertown, Mass.	Mechanical Engineer, B. F. Sturtevant Co., Jamaica Plain, Mass.	1899
SOLBERG, HALVOR C. Brookings, S. D.	Professor of Mechanical Engineering, South Dakota Agricultural College	1894
SPALDING, FREDERICK P. Ithaca, N. Y.	Assistant Professor of Civil Engineering, Cornell University	1893
SPANGLER, H. W. Philadelphia, Pa.	Professor of Mechanical Engineering, University of Pennsylvania	1893
SPERR, FREDERICK W. Houghton, Mich.	Professor of Civil and Mining Engineering, Michigan College of Mines.	1896
SPINNEY, LOUIS B. Ames, Iowa.	Professor of Physics and Electrical Engineering, Iowa State Agricultural College	1899
SPRINGER, FRANK W. Minneapolis, Minn.	Instructor in Electrical Engineering, University of Minnesota	1896
STALEY, CADY Cleveland, Ohio.	President, Case School of Applied Science	1894
STANWOOD, JAMES B. Cincinnati, Ohio.	Director, Technical School of Cincinnati	1894
STEVENS, JAMES S. Orono, Me.	Professor of Physics, University of Maine	1898
STEWART, CLINTON B. Anchor, Ill.	Civil Engineer	1894
STEWART, LEWIS B. Toronto, Ontario.	Lecturer in Surveying, School of Practical Science	1897
STOUT, OSCAR VAN P. Lincoln, Neb.	Associate Professor of Civil Engineering, University of Nebraska	1894
STRATTON, SAMUEL W. Chicago, Ill.	Associate Professor of Physics, University of Chicago	1893

NAME AND ADDRESS.	TITLE.	DATE OF MEMBERSHIP.
STUBBS, JOSEPH E. Reno, Nev.	President, Nevada State University	1897
STURDEVANT, CHAS. R. Louisville, Ky.	Assistant Professor of Electrical Engineering, Kentucky Agricultural and Mechanical College	1899
SWAIN, GEORGE F. Boston, Mass.	Professor of Civil Engineering, Massachusetts Institute of Technology	1893
TALBOT, ARTHUR N. Urbana, Ill.	Professor of Municipal and Sanitary Engineering, University of Illinois	1893
TAYLOR, WILLIAM D.		1894
THOMAS, ROBERT G. Charleston, S. C.	Professor of Mathematics and Engineering, South Carolina Military Academy	1894
THOMPSON, WILLIAM A. Columbus, O.	President, Ohio State University	1899
THORNBURG, CHARLES L. South Bethlehem, Pa.	Professor of Mathematics, Lehigh University	1894
THURSTON, ROBERT H. Ithaca, N. Y.	Director of Sibley College, Cornell University	1893
TIMMERMAN, ARTHUR H. Rolla, Mo.	Professor of Physics, School of Mines and Metallurgy, University of Missouri	1894
TOWLE, WILLIAM M. State College, Pa.	Assistant Professor of Practical Mechanics, Pennsylvania State College	1895
TRAMMEL, ROBERT J. Auburn, Ala.	Instructor in Mechanical Department, Alabama Polytechnic Institute	1896
TURNEAURE, FREDERICK E. Madison, Wis.	Professor of Bridge and Sanitary Engineering, University of Wisconsin	1894
TURNER, DANIEL L. Cambridge, Mass.	Instructor in Surveying and Hydraulics, Lawrence Scientific School, Harvard University	1898
TYLER, HARRY W. Boston, Mass.	Professor of Mathematics, and Secretary, Massachusetts Institute of Technology	1894
VAN ORNUM, J. L. St. Louis, Mo.	Professor of Civil Engineering, Washington University	1895

NAME AND ADDRESS.	TITLE.	DATE OF MEMBERSHIP.
VEDDER, HERMAN K. Agricultural College, Mich.	Professor of Mathematics and Civil Engineering, Michigan State Agricultural College.	1894
VOIT, ERNST Munich, Bavaria.	Professor of Physics and Electricity, Koenigliches Polytechnikum	1894
WADDELL, J. A. L. Kansas City, Mo.	Consulting Bridge Engineer, of Waddell and Hedrick	1893
WADSWORTH, JOEL E. Middletown, Conn.	Civil Engineer	1895
WADSWORTH, M. Edward Bessemer, Mich.	Geologist	1895
WALDO, CLARENCE A. Lafayette, Ind.	Professor of Mathematics, Purdue University	1897
WALKER, ELTON D. Schenectady, N. Y.	Assistant Professor of Civil Engineering, Union College	1895
WEBB, HOWARD S. Orono, Me.	Instructor in Mechanical Engineering, University of Maine	1897
WELLS, JAMES H. Missoula, Mont.	Assistant Professor of Mechanical Engineering, University of Montana	1897
WERNICKE, PAUL Lexington, Ky.	Professor of Modern Languages, Kentucky Agricultural and Mechanical College	1897
WHIPPLE, GEORGE C. Brooklyn, N. Y.	Director of Mt. Prospect Laboratory, Flatbush Ave. and Eastern Parkway.	1896
WHITNEY, NELSON O. Madison, Wis.	Professor of Railway Engineering, University of Wisconsin	1893
WILCOX, RALPH M. South Bethlehem, Pa.	Instructor in Civil Engineering, Lehigh University	1894
WILLETT, JAMES R. 434 Jackson Boulevard, Chicago, Ill.	Architect	1896
WILLIAMS, SYLVESTER N. Mt. Vernon, Iowa.	Professor of Civil Engineering, Cornell College	1893
WILLISTON, ARTHUR L. Brooklyn, N. Y.	Director Department of Science and Technology, Pratt Institute	1897
WILMORE, JOHN J. Auburn, Ala.	Professor of Mechanical Engineering, Alabama Polytechnic Institute	1894

NAME AND ADDRESS.	TITLE.	DATE OF MEMBERSHIP.
WILSON, VICTOR T. Ithaca, N. Y.	Instructor in Freehand and Mechanical Drawing, Cornell University	1898
WING, CHARLES B. Stanford University, Cal.	Professor of Structural Engineering, Leland Stanford Junior University	1895
WOOD, ARTHUR J. New York, N. Y.	Associate Editor 'Railroad Gazette,' 32 Park Place	1898
WOODWARD, CALVIN M. St. Louis, Mo.	Professor of Applied Mechanics, and Dean of Faculty of Pure Science, Washington University	1894
WOODWARD, ROBERT S. New York, N. Y.	Professor of Mechanics, Columbia University	1893
WRIGHT, CHARLES H. C. Toronto, Ontario.	Lecturer in Architecture, School of Practical Science	1897
ZIWET, ALEXANDER Ann Arbor, Mich.	Professor of Mathematics, University of Michigan	1897

GEOGRAPHICAL DISTRIBUTION OF MEMBERS.

Alabama	6	Michigan	12	South Dakota	2
Arkansas	1	Minnesota	11	Tennessee	3
California	4	Mississippi	1	Texas	3
Colorado	4	Missouri	8	Vermont	2
Connecticut	4	Montana	1	Virginia	2
Delaware	1	Nebraska	5	West Virginia	2
Illinois	14	Nevada	1	Wisconsin	9
Indiana	14	New Hampshire	3	Canada	6
Iowa	6	New Jersey	4	England	3
Kansas	3	New Mexico	1	France	1
Kentucky	5	New York	31	Switzerland	1
Louisiana	3	Ohio	18	Germany	2
Maine	6	Pennsylvania	15	Addresses unknown	2
Maryland	1	Rhode Island	2		——
Massachusetts	26	South Carolina	2	Total	251

37 States, 1 Territory, Canada and 4 European Countries.

DECEASED MEMBERS.

NAME.	YEAR OF ELECTION.	DATE OF DEATH.
CHARLES B. BRUSH	1893	June 3, 1897.
ECKLEY B. COXE	1894	May 13, 1895.
FRANCIS R. FAVA, JR.	1894	March 28, 1896.
JUSTUS M. SILLIMAN	1894	April 15, 1896.
JAMES H. STANWOOD	1894	May 24, 1896.
ALPHONSE N. VAN DAELL	1897	March 28, 1897.
JOHN R. WAGNER	1894	January 21, 1899.
FRANCIS A. WALKER	1896	January 5, 1897.
DE VOLSON WOOD	1893	June 27, 1897.

PAST OFFICERS.

Special Committee for Division E (Engineering Education), World's Engineering Congress, 1893.

IRA O. BAKER, Chairman,
WM. R. HOAG, Secretary,
MORTIMER E. COOLEY,
HENRY T. EDDY, Vice-Chairman,
C. FRANK ALLEN, Secretary, *pro tem.*,
SAMUEL W. STRATTON,
STORM BULL.

PRESIDENTS.

DE VOLSON WOOD,* 1893–4,
GEORGE F. SWAIN, 1894–5,
JOHN B. JOHNSON, 1897–8,
MANSFIELD MERRIMAN, 1895–6,
HENRY T. EDDY, 1896–7,
THOMAS C. MENDENHALL, 1898–9.

VICE-PRESIDENTS.

SAMUEL B. CHRISTY, GEORGE F. SWAIN, 1893–4,
ROBERT H. THURSTON, FRANK O. MARVIN, 1894–5,
FRANK O. MARVIN, CADY STALEY, 1895–6,
JOHN GALBRAITH, JOHN M. ORDWAY, 1896–7,
THOMAS C. MENDENHALL, HARRY W. TYLER, 1897–8,
C. FRANK ALLEN, HENRY W. SPANGLER, 1898–9.

TREASURERS.

STORM BULL, 1893–5,
JOHN J. FLATHER, 1895–9.

SECRETARIES.

JOHN B. JOHNSON, 1893–5,
C. FRANK ALLEN, 1895–7,
ALBERT KINGSBURY, 1897–9.

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* Died, June 27, 1897.

Members of Previous Councils.

Terms of Office Expired in 1894.

M. E. Cooley,
H. T. Eddy,
W. F. M. Goss,
W. R. Hoag,
S. W. Robinson,
H. W. Spangler,
R. H. Thurston.

Terms of Office Expired in 1895.

H. T. Bovey,
W. H. Burr,
O. H. Landreth,
Mansfield Merriman,
W. G. Raymond,
G. F. Swain,
De Volson Wood.*

Terms of Office Expired in 1896.

I. O. Baker,
Storm Bull,
S. B. Christy,
John Galbraith,
J. B. Johnson,
F. O. Marvin,
C. D. Marx.

Terms of Office Expired in 1897.

H. T. Eddy,
J. J. Flather,
J. P. Jackson,
Albert Kingsbury,
L. S. Randolph,
S. W. Robinson,
R. H. Thurston.

Terms of Office Expired in 1898.

C. F. Allen,
C. L. Mees,
Mansfield Merriman,
J. M. Ordway,
W. G. Raymond,
Cady Staley,
R. S. Woodward.

Terms of Office Expired in 1899.

Arthur Beardsley,
Robert Fletcher,
John Galbraith,
William Kent,
T. C. Mendenhall,
W. H. Schuerman,
M. E. Wadsworth.

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*Died, June 27, 1897.

CONSTITUTION

OF THE

Society for the Promotion of Engineering Education.

1. NAME.—This organization shall be called the SOCIETY FOR THE PROMOTION OF ENGINEERING EDUCATION.

2. MEMBERS.—Members of the Society shall be those who occupy, or have occupied, responsible positions in the work of engineering instruction, together with such other persons as may be recommended by the Council.

Honorary Members of the Society shall be such persons as may be recommended by unanimous vote of the Council after a letter ballot. They shall not have the right to vote, shall not be eligible to office, and shall not be required to pay any fees or dues.

The name of each candidate for membership shall be proposed in writing to the Council by two members to whom he is personally known. Such names, if approved by the Council, shall be voted on by the Society at the annual meetings.

3. OFFICERS.—There shall be a President, two Vice-Presidents, a Secretary and a Treasurer, each to hold office for one year. They shall be chosen by vote of the members at the annual meeting.

4. COUNCIL.—The Council of this Society shall consist of twenty-one elective members, one-third of whom shall retire annually. The officers and the past Presidents of the Society shall be members of the Council *ex officiis.*

Any member of this Society shall be eligible to election to the Council, provided that not more than one elective member shall be from any one college.

Members of the Council shall be elected by ballot by the Society, at its annual meeting.

The Council shall constitute a general executive body of the Society, pass on proposals for membership, attend to all business of the

Society, receive and report on propositions for amendments to the constitution, and shall have power to fill temporary vacancies in the offices.

5. Fees and Dues.—The admission fee shall be three dollars, and the annual dues three dollars, payable at the time of the annual meeting. Those in arrears more than one year shall not be entitled to vote, nor to receive copies of the proceedings, and such members shall be notified thereof by the Secretary one month previous to the annual meeting. Any member who shall be in arrears more than two years and shall have been duly notified by the Secretary, shall be thereby dropped from the roll, excepting such arrearage shall be paid previous to the next ensuing annual meeting; and no such member shall be restored until he has paid his arrears.

6. Meetings.—There shall be a regular meeting occurring at the time and place of the meeting of the American Association for the Advancement of Science, or of some one of the National Engineering Societies, or otherwise as the Council may determine.

7. Publication.—The Proceedings of the Society, and such papers or abstracts as may be approved by the Council, shall be published as soon as possible after each annual meeting.

8. Amendments.—This Constitution may be amended by a two-thirds vote at any regular meeting, after having been approved by a two-thirds vote of the Council, taken by letter ballot.

RULES GOVERNING THE COUNCIL.

First. The officers of the Society shall constitute a committee to arrange the time and place of the annual meeting, and also to prepare a program for the same.

Second. The reading of papers shall be limited to fifteen minutes each, and abstracts of the same of about three hundred words or less shall be printed when practicable and distributed in advance to the members.

Third. The time occupied by each person in the discussion of any paper shall not exceed five minutes.

PROCEEDINGS.

THURSDAY, AUG. 17, 1899.

MORNING SESSION, 10 O'CLOCK.

The seventh annual meeting of the SOCIETY FOR THE PROMOTION OF ENGINEERING EDUCATION was held at Townshend Hall, Ohio State University, Columbus, Ohio, immediately preceding the meeting of the American Association for the Advancement of Science.

The meeting was called to order by the President, Dr. Thomas C. Mendenhall, who introduced Dr. William O. Thompson, President of the Ohio State University. Dr. Thompson, in a brief address, extended a cordial welcome to the Society, to which President Mendenhall responded.

The annual report of the Secretary was read and accepted, and that of the Treasurer referred to an Auditing Committee to be appointed by the President.

The following persons, whose applications for membership had been approved by the Council, were duly elected: Frank E. Sanborn, James Fisher, Jr., James D. Phillips, Walter B. Snow, George R. Chatburn, Joseph D. Harper, Louis B. Spinney, Morgan Brooks, Samuel W. Beyer, Benjamin F. Groat, Barton Cruik-

Library

shank, William F. Durand, Robert H. Fernald, Frank W. Brady, Edward C. Burnham, Edward C. Schmidt, John T. Faig, Charles R. Sturdevant, Edward Robinson, Walter K. Palmer.

Professor Magruder, representing Professor Orton, extended an invitation to the Society to visit Minerva Park on Friday evening, as the guests of the Columbus Engineers' Club. This invitation was, on motion, accepted with thanks.

The Secretary reported that the Council, at its session that morning, had considered the interpretation of Article 5 of the Constitution, relating to fees and dues, and had decided to recommend to the Society that it be interpreted as meaning that the first payment of three dollars shall cover both the admission fee and the dues for the first year. On motion, this recommendation was approved, and the Secretary instructed to take the necessary steps to bring about a change in the wording of the article, in accordance with that interpretation.

It was voted that the Chair appoint a Nominating Committee to report a list of candidates for the offices and for the Council.

The regular exercises were begun with the delivery, by the President, of the Annual Address.

The Secretary read a paper by Professor A. L. Rice on "The Essentials of a Technical Education."

Professor W. T. Magruder read a paper on "The Engineering Educational Value of a Refrigerating Plant."

The program of the morning was concluded with the reading, by the Secretary, of a paper on "Advanced Algebra in Engineering and other College Courses," by Professor F. L. Emory. The discussion of this paper was postponed till the afternoon session.

The meeting then adjourned to the afternoon session.

AFTERNOON SESSION, 2 O'CLOCK.

President Mendenhall in the chair.

Professor Edgar Marburg presented a paper on "The Correspondence School in Technical Education," which was discussed by Professors Merriman, Williston, Aldrich, Marburg, Hatt, Waldo, Magruder, Allen and Mendenhall.

The discussion of the paper, read at the morning's session, on "Advanced Algebra in Engineering and other College Courses," by Professor F. L. Emory, was taken up and participated in by Professors Merriman, Hatt, Bohannan, Mees, S. W. Robinson and McNair.

This was followed by a paper on "The Hydrocarbon Engine Testing Plant of the Ohio State University," by Professor W. T. Magruder.

The President announced the following appointments on committees:

Auditing Committee: Professors Waldo and Williston; Nominating Committee: Professors Merriman, Eddy and Magruder.

The meeting then adjourned to make a tour of inspection of the various buildings of the Ohio State University.

Friday, August 18, 1899.

MORNING SESSION, 9:30 O'CLOCK.

Vice-President Allen in the chair.

The Secretary reported that the Council had taken favorable action on the applications for membership of Benjamin F. La Rue, George B. Halstead, Edward A. Bending, Rosser D. Bohannan and Thomas E. French, and on motion they were declared elected.

The Committee on Nominations presented the following names of candidates for the Council: Brown Ayres, Tulane University; G. W. Bissell, Iowa State Agricultural College; J. J. Flather, University of Minnesota; W. T. Magruder, Ohio State University; F. W. McNair, Michigan School of Mines; J. M. Porter, Lafayette College; A. J. Wood, of the *Railroad Gazette.*

The election of these nominees resulted by a unanimous vote.

The Nominating Committee then announced the following nominations for officers:

President, Ira O. Baker, University of Illinois.

Vice-Presidents, Robert Fletcher, Dartmouth College; C. D. Marx, Leland Stanford University.

Treasurer, C. A. Waldo, Purdue University.

Secretary, Edgar Marburg, University of Pennsylvania.

The regular program of papers was then resumed with the reading, by the Secretary, of the paper on "The Relative Distribution of the Instructing Force in Collegiate Departments," by Professor J. P. Jackson. This paper was discussed by Professors Bull, Jacoby, Waldo, Marburg and Allen.

Professor Allen then read a paper on "Methods of Teaching Engineering: by Text-book, by Lecture, by Design, by Laboratory, by Memoir," which was discussed by Professors Mees, Williston, McNair, Caldwell, Hatt and Allen.

The presiding officer resigned the chair to President Mendenhall and the program was continued with the reading and discussion of the following papers:

"A Catalogue and Clipping Case," by Prof. W. T. Magruder; discussed by Professors Bissell, H. E. Smith, Jacoby, Sanborn, Allen, Magruder and Mendenhall.

"Engineering Education and Expansion," by Prof. W. S. Aldrich.

The meeting then adjourned to the afternoon session.

AFTERNOON SESSION, 2 O'CLOCK.

President Mendenhall in the chair.

The meeting was begun with the reading by the Secretary of a paper on "A Convenient Laboratory Equipment for the Study of Direct Current Dynamos and Motors," by Professor H. B. Smith.

Prof. F. C. Caldwell then read a paper on "A Comparative Study of the Electrical Courses Given at Different Institutions."

This was followed by the presentation of a paper by Prof. H. E. Smith on "Drawing, Mechanical Laboratory Practice and Shop Work in Engineering Colleges."

The succeeding paper by Professor O. G. Hood on "An Apprentice System in College Shops," was discussed by Professors Caldwell, Hood, S. W. Robinson, Aldrich and Waldo.

The program for the day was closed with the paper by Prof. C. R. Jones on "Elective Studies in Engineering Courses," which was discussed by Professors Bull, H. E. Smith, Allen, Sanborn, Jacoby, Hatt, Robinson, Caldwell, Reber, Aldrich, Eddy and Mendenhall.

Prof. Aldrich moved that the chair appoint a committee to report at the next annual meeting of the Society on the general subject of elective studies in engineering courses.

Prof. Robinson proposed as an amendment to this motion, that the question of the appointment of such a committee be referred to the Council. This amendment was accepted and the motion, as amended, carried.

The Secretary announced that at the last annual meeting, the question of the enlargement and continuance of the Committee on "Entrance Requirements," and the continuance of that on "Uniformity of Symbols," had been left to the Council; that a letter ballot of the full Council had been ordered, and had resulted in a vote favorable to the first and adverse to the second proposition.

The meeting then adjourned till the following morning.

Saturday, August 19, 1899.

MORNING SESSION, 9:30 O'CLOCK.

President Mendenhall in the Chair.

The proceedings were begun with the election to membership of the following candidates, whose applications had been duly endorsed by the Council: Wm. A. Thompson, Wm. H. Browne, Jr., Embury A. Hitchcock, Nathaniel W. Lord.

The first paper of the day, by Professor A. E. Haynes, on "The Desirability of Uniformity in the Use of Mathematical Symbols and Terms; and How to Secure such Uniformity" was, in the absence of the author, read by Professor Eddy and was discussed by Professors Waldo and Eddy.

This was followed by the reading of a paper by Professor Albert Kingsbury, entitled "On the Nature of Entropy," which was briefly discussed by Professors Eddy and R. S. Woodward.

The literary exercises of the meeting were concluded with a paper by Mr. F. W. Springer on "Direct Current Laboratory Work in an Electrical Engineering Course," which was read by Professor Allen.

The persons proposed for officers, by the Nominating Committee, at the morning session of the preceding day, were then elected by a unanimous vote.

The President announced that, by vote of the Council, back volumes of the Proceedings, needed for the completion of the personal files of members, would hereafter be furnished by the Secretary for $1.50 per volume, postpaid.

Professor Waldo, Chairman of the Auditing Committee, reported that the Treasurer's accounts had been examined and found correct.

Professor Marburg moved that the Council be requested to consider the question of the appointment of a committee to report upon the means by which the Society might best assist in a movement for the promotion of industrial education in the United States. This motion was carried.

The meeting then passed a standing vote of thanks to the Ohio State University, to the Engineers' Club of Columbus, and to the Local Committee for the many courtesies received at their hands.

The meeting was thereupon declared adjourned.

REPORT OF THE SECRETARY.

The Society enters upon its seventh year in a vigorous condition. Its membership is increasing steadily; the interest of its members in the work of the meetings is greater than ever before; and the Society's financial condition is such as to be a source of satisfaction to all.

The membership list for the past year shows two hundred and forty-four names, an increase of eighteen over the previous year.

In advance of fuller notices to be printed in the Proceedings, the Secretary may here state that the Society has lost by death two members; John R. Wagner, who died January 21, 1899; Alphonse N. Van Daell, who died March 27, 1899.

There have been four resignations from the membership; thus the actual membership at the beginning of this annual meeting is two hundred and thirty-eight.

Respectfully submitted,

ALBERT KINGSBURY, *Secretary.*

REPORT OF THE TREASURER.

The Treasurer would respectfully report as follows:

The total receipts during the year 1898–1899 from various sources, as given in the itemized statement herewith, have been $1367.42 of which $567.00 were for current dues.

There is at present a balance of $208.68 on hand with practically all bills paid.

During the year the treasury has paid for the printing of two Volumes, V. and VI., which accounts for the unusally large item for printing.

The item $220.15, nearly four times as large as the corresponding one for 1897–1898, shows a gratifying increase in the demand for the Proceedings from outside sources.

A condensed statement of receipts and disbursements for the year is appended herewith:

RECEIPTS.

By cash on hand August 17, 1898	$ 423.72
By sale of Proceedings	220.15
By reprints of papers	35.55
By initiation fees	57.00
By past dues	64.00
By current dues	567.00
Total	$ 1367.42

DISBURSEMENTS.

To stenographer's services, Boston meeting	$ 60.00
To printing Proceedings, reprints and circulars	903.36
To postage and stationery	15.84
To typewriting	38.41
To Committee on Entrance Requirements	26.19
To Secretary's expense account	105.13
To revenue stamps and exchange on checks	2.71
To incidentals	7.10
To cash on hand	208.68
Total	$ 1367.42

JOHN J. FLATHER, *Treasurer.*

August 17, 1899.

REPORT OF THE AUDITING COMMITTEE.

Columbus, Ohio, August 19, 1899.

To the Society for the Promotion of Engineering Education:

Your Auditing Committee find the report of John J. Flather, Treasurer, to be correct and that $208.68 as contained therein is the true balance due the Society.

Signed, C. A. WALDO,
A. L. WILLISTON,
Auditing Committee.

ADDRESS BY THE PRESIDENT.

PROFESSOR THOMAS C. MENDENHALL,

President Worcester Polytechnic Institute, Worcester, Mass.

The Presidency of a Society which embraces in its membership representatives of all the leading schools of engineering and applied science in this country is an honor which one may not lightly accept or indifferently bear. Although not established by its organic law, its traditions make it the duty of the presiding officer to present an address which should be, in spirit at least, worthy of so important an occasion. Happily for those upon whom this honor may fall, custom has not yet restricted or defined the sphere of discussion which shall be thought suitable for such a paper; on the contrary one may properly take advantage of this oportunity to become temporarily a *ronin*, a free lance, attacking everything and everybody, seeking only to give full and fair exposition of one's own personal, and, may be, peculiar views. This is the one compensation going with the burden which the Society insists must accompany the honors which it bestows. No apology is needed, therefore, for the selection of a topic the consideration of which may seem more or less irrelevant and unnecessary to some, and, perhaps, unwelcome to others. In the present instance the choice is due to a strong conviction that schools of engineering are, for the most part, far from doing their full duty in an important matter, namely, the inculcation and dissemination of sound views, both theoretical and practical, relating to scientific metrology.

We cannot ignore the fact that the general public, even the intelligent public, receives its information regarding scientific and technical questions almost entirely from daily newspapers and popular magazines, than which, we will all admit, there could hardly be a more untrustworthy source. The wide-spread taste for sensationalism by which we are now cursed, a taste which seems to grow with the efforts made to satisfy it, offers a premium upon anything startling or revolutionary, giving little heed to sober, everyday truth. If one-tenth of the wonderful scientific discoveries that have been announced with glaring headlines in the public press within the last five years had actually been made it would, indeed, have been an epoch-making period; but fortunately for everybody they existed mostly in the brilliant imagination of the space writers who alone were benefited by their publication. If this were all, we could afford to be indifferent, but there is the further disagreeable fact that a large number of intelligent people are led to look upon this sort of thing as real science and few of us have an adequate conception of the extent of this delusion. One of the results is that in science as in many other things, those who do the real work of the world fail to be credited with it, while the people are lavish in their praise of those whom they believe to be worthy. Only a few weeks since, I found in an article on teaching history, written by the Superintendent of Schools in a large city, the names of a quartet of Americans most distinguished in war and in peace. Three of the four were Washington, Lincoln and Franklin. As this is not meant to be a humorous paper I will not mention the fourth, contenting myself with saying that in this instance the newspaper had done its work well.

A curious and, in my judgment, a seriously instructive example of the readiness with which people accept newspaper science is found in the attempt made a year or two ago to fix the value of the ratio of the circumference to the diameter of a circle by legislative enactment. This incident may be familiar to some of you, but it is entirely worthy of consideration by those to whom is entrusted a large share of the instruction in exact science in American Colleges. The legislative body involved was not one of a State south of Mason and Dixon's line, nor west of the Mississippi River. It was a body chosen by the people of one of the greater states of the Union: one deservedly enjoying considerable distinction, especially in literary circles, on account of the eminent men it has produced and also for the excellence of its educational institutions. In this legislature, House Bill No. 246 was entitled "A Bill for an Act Introducing a New Mathematical Truth * * *" which truth, in the second section of said bill, turns out to be that the circumference of a circle is just three and one-fifth times its diameter. In the capital of the state is published a daily morning paper of unusual excellence. Not generally given to sensationalism, its contents are usually clean and wholesome, its news well collected and arranged, and even a single copy gives the impression that it is an example of the better phases of journalism. Yet this paper devoted more than two columns of its first page to an exploitation of this most important discovery, which had been made by a physician living in an obscure corner of the state. It was announced that the laws of the quadrature had been copyrighted and that this newspaper was allowed to be the first to make them public, this privilege being, without doubt, the bait which caught the uninformed editor. Some measure of his credulity may be found in his sober declaration that the circle-squarer's demonstration had been accepted by all eminent mathematicians; that the "American Mathematical Journal, the highest authority in the country," had hastened to publish it and this publication instantly attracted the attention of the scientific journals in Paris, the editors of which had eagerly sought contributions from the author of the discovery. The solution had been copyrighted in the United States and in England, Germany, Belgium, France, Austria, Italy and Spain. At Washington it had won the support of the professors of the National Astronomical Observatory, Professor Asaph Hall, "whose fame was secure with the discovery of the moons of Mars," being especially delighted with it and finding in it a complete explanation of a hitherto unexplainable anomaly in the earth's motion. The desk of the discoverer was full of letters from leading mathematicians in Europe and America and one from his agent in London proved that his demonstration had been shown to Tyndall and Huxley who warmly endorsed its accuracy. Professors in Ann Arbor and from Johns Hopkins University had seen the demonstration and declared it perfect. I leave to the guardians of the name and fame of these institutions and to others referred to, the task of ascertaining just what lineal descendant of Ananias was at that time on the editorial staff of this journal; but the actual disposition of the bill by the legislative body is a matter of much interest. When first introduced it was taken humorously by the Speaker of the House, who happened to be a graduate of a widely known educational institution, and he ordered its reference to the Committee on Swamp Lands. Two days later, however, the great discoverer had a hearing before the State Superintendent of Public Schools and the Committee on Education, who at once endorsed the solution; the Committee on Canals and Swamp Lands reported House Bill No. 246 back, with a recommendation that it be referred to the Committee on Education; the latter committee gave the bill careful consideration and reported "the same back to the House, with the recommendation that the said bill do pass"; the bill was called up by the committee and, *mirabile dictu*, the bill actually passed that branch of the legislature, by what was reported to be a good, safe majority. Before it actually became a law, however, its character began to be recognized and its further progress was arrested. The possibility of such an incident, at the very end of the nineteenth century is a fact from which some useful inferences may be drawn and a just allotment of responsibility might well cause some anxiety.

But it is not to the particular kind of metrological reform suggested by this incident that I desire to ask your special attention. Josephus says that Cain "broke the tranquility of the world by introducing weights and measures," and it is perhaps not without significance that the first exponent of precise measurement was also the first homicide. At any rate, it will not be denied that the welfare of mankind has been enormously affected by the development of the art of weighing and measuring, and the importance of this art has grown with the perfection and complication of enlightened society. The systems of metrology in general use among English speaking people at the present time have come to us from remote, almost prehistoric time, through Greece and Rome, and thousands of years have passed without any marked improvement in them, except in the betterment of fundamental standards, the interrelation of which is still as essentially illogical and unscientific as in the beginning.

As every one knows, the nineteenth century has witnessed a marvelous metrological reform among nearly all other races, and it is of this reform, never so important to us as just now, that I propose to speak. I am glad to be able to assume in the beginning that you are all quite familiar with the general facts relating to this controversy, and I ask your consideration of the subject, not because of any lack of knowledge on your part, but rather because of my belief, already expressed, that you and the work you stand for have failed in a large measure, perhaps for lack of interest, in the active dissemination among the general public, of the principles and advantages of a reformation of vital consequence to their material welfare.

A brief review of existing conditions will be of use to those who have not given the subject serious thought. It is not generally known that the legal, fundamental standards of length and mass in this country are as numerous as the States of the Union. It will not do to say that these are identical, for they are not and cannot be, and many of their derivatives are decidedly different. There is a wide-spread notion that there is a United States standard pound which is everywhere legal, and a yard of the same authoritative origin, but this is an error, for these are only legal in transactions to which the general government is a party, and then only by authority of the Secretary of the Treasury. There is but one commodity which must everywhere, and always be measured by one standard, and that is the coinage. And even this is nominally, not actually, referred to a material standard, legalized over seventy years ago, which is obsolete in form and construction, "without pride of ancestry or (let us be thankful) hope of posterity." Practically, we ignore all legislation in the matter of fundamentals and universally accept standards of mass and length from two to three prominent makers who have mostly adopted those of the U. S. Office of Weights and Measures. There is much local legislation, however, on derived measures and much confusion results therefrom. As an example, an Act passed by the State of Massachusetts only five years ago may be cited. It legalizes *twenty-six* different bushels in one section while in another it declares that a bushel *in heap measure* shall contain 2150.42 cubic inches, this being the volume of the well known Winchester bushel when flat or struck, as used by the U. S. Government and almost everywhere in this country. It also legalizes a dry gallon of 282 cubic inches, together with the liquid gallon of 231 cubic inches, which the National Government uses, thus creating an absolutely unnecessary and extremely annoying confusion. In one state there is a law that innkeepers "shall sell beer and ale by wine measure to all persons as drink it in their houses and by beer measure to all persons as carry the same out of their houses"; in another, and this in New England, it was enacted comparatively recently that in measuring certain commodities "one bushel and three quarters of a peck shall be deemed a bushel." In spite of legislation in many states fixing the value of a barrel at 31½ gallons it contains in these same states, almost invariably 40 or 42 gallons. In one State a gallon of milk must contain 231 cubic inches; in another its capacity is fixed at 282 cubic inches. Not only is the value of a bushel when determined by weight different for different commodities, but for the same commodity there is great variation among different states of the Union, amounting, in many instances, to fifty and seventy-five per-cent. I need not consume your time in relating the many other inconsistencies and absurdities inherent in our present system, such as the variety of meanings attached to the word ton; not less than three or four in number; the confusion of pounds, ounces, etc.; the elusive and uncertain meaning of perch. With all of these and many others you are already familiar, and the whole system is so fearfully and wonderfully made that it may be safely affirmed that no man lives who knows and understands all of it.

Nor is it necessary for me to consider the origin and nature of the system which those interested in metrological reform wish to see installed in its place. Most if not all of you know it very well and have been accustomed to make use of it in a greater or less degree. The innumerable advantages of a system of metrology as simple and as scientific as that known as the metric system are now all but universally admitted. They have been written about and talked about and learned by actual use to such an extent that a presentation of them here would be a waste of time. I prefer to briefly consider a few of the more important arguments that have been made against this system or against its use in this country. There is a certain class of objectors, small in number, quite unworthy of serious consideration. Among them are those who see something sacred in the yard and the pound, because they are relics of antiquity, and something inherently wicked in the metre and the kilogramme because they originated with the French during the Revolution at the close of the last century. To some of them the very mention of the metric system is like a red flag to an anarchist, and two or three of them have published elaborate but tiresome arguments against the proposed reform, abounding in inaccurate statements and illogical and unscientific propositions. They mostly reveal a condition of intellectual atrophy over which it is but common charity to draw the veil of silence. There are, however, some criticisms of the metric system that are entitled to the most serious consideration on the part of its friends and some of them are urged by those who would gladly welcome metrological reform if it came in a way which met with their approval. The advocates of the metric system not only do not wish to avoid rational criticism but they heartily desire it, believing that the more widely it is known and discussed, the more its advantages are understood, the more enthusiastic supporters it will have.

One of the commonest arguments against it, one well known to all of you, I am sure, is that it is decimal and not duo-decimal or binary, or based upon some divisor other than ten. One may admit, for the sake of argument, that there would be advantage in subdividing a unit by continual bisections, but the extremely limited area to which this advantage would be restricted is almost universally overlooked. It is forgotten that it is only when measurements are the result of estimation or judgment that this superiority would be felt. This being admitted it further follows that the exercise of judgment, wherein bisection may possess an advantage, occurs only when a single undivided unit is under consideration, and who will claim for a single instant that the difficulty of estimating a fraction of a unit is in the least dependent on whether that unit is itself the tenth or the eighth or the twelfth of another? The plain fact is that if one is contemplating the metre as a unit it is just as easy to think of or to set off a half quarter, or eighth or sixteenth part as if it were a yard, and the same is true of the decimetre or the centimetre when compared with the foot or inch. Indeed one who is accustomed to use the metric system speaks and thinks of a half or quarter centimetre or a half or quarter millimetre without the slightest embarrassment, never imagining that he is in the least inconsistent or "disloyal" to the decimal system. It is curious that this objection should be urged by people who have long ago become accustomed to a like condition of things in their currency and who would be extremely unwilling to go back to a system non-decimal in character. No one will pretend that the subdivision of 'a dollar offers any inconvenience and every one knows that the superiority of the decimal system in currency is so manifest that nearly all nations have adopted it in one form or another. Whatever disadvantages might be anticipated in the use of the dollar or the metre with decimal subdivisions are involuntarily destroyed by the natural tendency to refer to smaller units rather than to continue bisections. `Thus we may talk of a half metre or a quarter metre, but for smaller quantities the decimetre or the centimetre are at once chosen, and when we wish to go below a half of a centimetre the millimetre offers itself as a convenient unit. In the same way we find no embarrassment in taking up the cent as a unit when it is desired to go below a quarter of a dollar. That the several units thus used are decimally related to each other is the one fact that makes all of this beautiful simplicity possible. I have ventured to elaborate somewhat upon this point because many people are of opinion that the fact that the radix is ten and not two is a really serious objection to the metric system. It is believed, however, that careful study of the principles involved, following the lines indicated above, will show that this fact is of no importance. And it must not be forgotten that our present system is anything but binary and that the adoption of almost any radix would be an enormous improvement. But above all of this it must be remembered that nobody claims any special virtue or unique qualities for the number *ten*. It is not because it is decimal that the metric system is so far superior to all others. That superiority rests on two great facts, the first of which is that the radix of the system is identical with that of the system of notation and numeration now and for many years in use by all civilized people. It may well be that a binary or duodecimal or some other system of notation would offer advantages over that which has probably fixed itself upon us for an indefinite future, but it is absurd to argue that metrological reform must wait upon a notational revolution. The probability of the latter is almost infinitely small, at least for centuries to come, while already a majority of civilized nations have adopted the decimal system of weights and measures. The other great fact on which the superiority of that system depends is the beautifully simple interrelation of units, resting upon constant physical properties of matter. No other system is for a moment comparable with it in this respect and this alone would entitle it to consideration and adoption by all progressive communities.

I pass over many more or less trivial objections to the metric system, all of which have been successfully answered many times, to take up one which is of far greater importance than all others, although it is not really a fault in the system itself. It is urged that the adoption of the system in this country must be accompanied by very large loss, especially among machinists and manufacturers, of accumulated material in the form of tools, machines, patterns, etc., which have been designed and made upon a basis of the foot or inch unit of length and which would be rendered useless by the introduction of the metre or centimetre. It is also argued that there would be great loss occasioned by the disuse of scales, balances, weights, etc., which would necessarily be replaced by metric measures. On these grounds several very able engineers have based a strenuous opposition to the proposed reform and their influence is freely admitted to be the most serious obstacle to its progress.

Against this argument a few incontrovertible facts are put. One of these is that only a relatively small proportion of tools and machines are in any way affected by the question of standards; another is that the life of a tool or machine in these days is comparatively short, not only on account of deterioration from use, but as well because of continual improvements which render designs only a few years old practically worthless. Much has been said about the enormous value of patterns for machinery and machine tools which have accumulated during a period of years and which would be rendered useless by the introduction of new standards. Concerning this it may be said that in many of the most extensive manufacturing establishments in this country, patterns once used are not considered as assets at all, the chances being that through the rapid improvement in design constantly going on they will shortly become obsolete. There is also the further fact, testified to by some important establishments in which the metric system has already replaced the old, that there is almost invariably enough to spare in a casting which is to be machine-finished to make it possible to work it to metric dimensions. In a similar way the possible cost of the reform due to the necessary change in apparatus and standards for weighing and measuring has been grossly overestimated. Balances will be, of course, not affected at all; platform and other scales can readily and cheaply be adapted to the new units. Those who have maintained a somewhat bitter opposition, based on this question of cost, to all suggested legislation looking to metrological reform, seem to have ignored two important considerations; the first is that the thing which they proclaim to be so difficult that it is practically impossible has already been accomplished and many times, by different European nations with almost no difficulty and under conditions vastly less favorable than those existing with us. The second is that no reasonable advocate of the metric system expects the transformation to be made in a night, or in a month or a year. The history of the adoption of our currency system furnishes a useful example of what may be expected. More than a generation elapsed after it became the legal system of the nation before its use was even approximately universal.

There is another objection to the metric system important enough to deserve examination and that is the alleged difficulty of understanding it and of becoming accustomed to its use, and it has been affirmed

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that this difficulty would be especially marked among mechanics and workmen of all classes who make frequent use of weights and measures. Here again we may best appeal to experience. To Germany, Austria, Italy, Spain and other European nations outside of France, the metric system came as a foreign innovation, but nowhere was any serious difficulty experienced. The same may be said of practically every nation on the American Continent, excepting the United States and Canada. Before a Parliamentary Committee Siemens testified concerning its introduction in his own works in Germany, that "it was all a matter of about a fortnight or three weeks; when the people were accustomed to it and did not ask for any more of the old measures, but asked for the new." In Germany the Adopting Act was passed in 1868, and the use of metric measures was made compulsory in 1872. Siemens testified that this actual adoption took place mostly between January 12, 1870, and January 1, 1872, and that when the compulsory time came there was nobody to be compelled. Other German testimony was of the same character; that knowing they had to be ready when the time came they were ready before the time came. Professor Foerster, Chief of the German Bureau of Weights and Measures, under whose direction the introduction of the metric system was made, has furnished us a most interesting account of how it took place. In speaking of the complaint, then common in Germany as it has been here, that the metre was too long, that "we can estimate by the foot and not by the metre," he makes the very suggestive remark that "experience has shown that here too, people have only hung a cloak around habit in order to hide its nakedness." You are doubtless all aware that a few years ago in the great English engineering establishment of Willans & Robinson the metric system was adopted to the entire exclusion of British measure. Their testimony was strongly in its favor and showed that English workmen very quickly adapted themselves to its use and when once they understood it, all agreed that it was much easier to work to than the English system. The head of their tool room testified that "it was a little awkward for a time" but that this lasted only about two days. Some of our own large manufacturing establishments having branches in Europe, such as the General Electric Company, have declared that they found a decided advantage in making and working to metric drawings. Indeed, there is an "embarrassment of riches" in testimony of this kind and I feel that I ought rather to apologize for bringing any of it before this body. We may justly regard the case as proven and the controversy closed, except as to the question of ways and means. If it be affirmed that there is no demand for the change, I could deluge the Society with resolutions of Chambers of Commerce, Boards of Trade, Manufacturers' Associations, Engineers' Clubs and Societies, Builders' Exchanges, Architects' Clubs, Pharmaceutical Associations, Trades Unions, Educational and Scientific bodies and other public organizations too numerous to even name. In England the past five years have witnessed what is little short of a revolution of sentiment on this question, the result of an agitation originating not among scientific men but with the so-called practical people. It is there, as it must soon be here, a question of vital importance to commerce and trade. The testimony of their far-sighted consular agents in various parts of the world is that British trade with all nations except our own is sadly handicapped by its units of measure, and our own consular reports are of the same tenor. Within a year we have entered upon a new era in our foreign relations. Our trade with foreign nations has increased enormously and must increase still further if we are to maintain our footing. We have already absorbed a considerable population by whom the metric system has long been used and our merchants and manufacturers are already feeling the disadvantages of our antique and irrational measures of quantity. Fortunately for us our principal competitors are the English, who are carrying nearly the same burden. But they have been quick to recognize the necessity for reform and in five years they have made more progress towards it than we have in thirty.

Schools of engineering and professors of engineering and applied science can do more, if they are so minded, to help their country in this emergency than any other agency that I know of. They can do it by a more liberal use of the metric system in their daily work. Electrical engineering, by a wonderful stroke of good fortune, emancipated itself from this curious slavery in the very beginning and its astonishingly rapid growth from infancy to the vigorous manhood which it now enjoys is very largely due to that fact. In the engineering college of to-day the student in physics and chemistry is brought into close relations with the metric system, but when he advances to his professional studies in civil and mechanical engineering he is too often compelled to relapse into the exclusive use of the foot, the pound and the gallon. I am far from recommending the abandonment, at this time, of these useful units, but I strongly urge the importance of allowing them to share their work with their metric analogues, and very liberally. Even if there were no other advantage there would be an enormous gain to the student in compelling him to do his problems and his laboratory exercises in more than one system of units, than which nothing contributes more to clearness of understanding and soundness of knowledge. If we had begun this a quarter of a century ago and kept it up, we should be in much less danger of being beaten in the race for the markets of the world than we are to-day; for this system is bound to become universal, and in the near future. The prodigious advantages which it offers in its simplicity, its economy and its already extensive use will insure this. No body of men can more effectively influence public sentiment to an appreciation of this fact than those I now address.

One of the ablest and most scholarly arguments in favor of the Metric System ever made was that of Charles Sumner in the Senate of the United States more than thirty years ago. He summarized the argument as follows: "A system of weights and measures born of philosophy rather than chance is what we now seek. To this end old systems must be abandoned. A chance system cannot be universal. Science is universal; therefore what is produced by science may find a home everywhere."

METHODS OF TEACHING ENGINEERING:

BY TEXT-BOOK, BY LECTURE, BY DESIGN, BY LABORATORY, BY MEMOIR

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In order to secure the best engineering product in any case, the engineer—he who follows the profession of engineering—must understand the nature of the material employed, the use to which it is to be put, and, if it is to be a machine, the nature of the article it is to produce. He must also understand the methods in use by which the material can be brought into the required form. In a similar way, the engineering educator—he who follows the profession of engineering teaching—in order to reach the best results, must well understand the nature of the material he is to use, his pupils; he must appreciate thoroughly what his pupils shall be expected to do after leaving his instruction; or to follow the simile of the machine, he must understand the engineering works which his pupils are to design and construct after graduation. But the educator must also understand the educational methods by which his pupils are to be rendered fit for the work which they are to do.

The engineering teacher then must of necessity be sufficiently an engineer to be able to appreciate adequately the nature of the engineering works which the educated engineer may be called upon to design and to construct. ' That the teacher should be facile and expert in actually designing and constructing such work is not essential. Yet it is true that actual experience in engineering practice is and always must be of great value to the teacher. The assurance that it gives, to the public and pupil alike, of competence in this direction is so important, that in the future as in the past, it will often, and with much propriety, be insisted on as a necessary qualification for the engineering teacher.

Furthermore, it is difficult at the best for any one to determine, without extended trial, the teaching ability of a young candidate for the position of engineering teacher; it is even more difficult, when, as is often the case, those charged with the selection of teachers are not themselves trained teachers and fail to appreciate the importance of the ability to teach. The ability in engineering of a candidate for a position, may, on the contrary, have been tested, and can commonly be rated with comparative ease and with reasonable accuracy. It is not unreasonable then that engineering educators should have been selected with reference more to their engineering than to their teaching ability. The tendency in this direction is enhanced by the fact that to us, as engineering teachers, the problems of engineering often seem more attractive than the problems of education. With the advantages of engineering experience so evident, and the taste for it so general, it has naturally resulted that engineering teachers have received little or no formal instruction or training in the study of the material, their pupils. Nevertheless, it is true that for the proper understanding of the engineering student whose nature is not quite that of boy, nor yet of man, but somewhat of school-boy and man combined, and for the adaptation of the instruction to the needs of the pupil, both as to substance and as to methods of presentation, the teacher is demanded rather than the engineer. The writer will readily acknowledge that the engineer may probably become a skillful teacher after practicing engineering if he appreciates the importance of the teaching side of his work, and perhaps the desirable preparation is of this sort.

In the judgment of the writer it admits of no doubt that a suitable course of study in psychology could be made of very great value to any of us as an aid to understanding human nature, and correctly judging the character, the qualities and abilities of our pupils. With this phase of preparation, however, this paper does not deal. Neither does it deal, except incidentally, with another side of the work of teaching, of superior importance, the determination of what subjects, or what part of subjects, shall form the course of study. This matter has already, in many cases and in many ways, been treated with ability before this Society.

The purpose of this paper is rather to discuss, as a part of the work of teaching, the method of presentation, rather than the substance of the matters taught. Even here we can hardly reach correct conclusions unless we have an adequate conception of what the finished product, the accomplished engineer, is to be, as well of what should constitute our part in the process of production. We receive the individual by no means in the rough, and part with him, already a useful implement, to be sure, but requiring a further process to make him thoroughly fit for the uses intended.

For the finished engineer there is required suitable material upon which to work. Upon this must be laid a theoretical training in the principles applicable to engineering, which shall be sufficient for the proper consideration of problems which he may reasonably be called upon to handle; and to this must be added finally, experience, or a knowledge of facts and details necessary for the successful solution of such engineering problems.

It is not to be expected that any engineering college will so conduct its work as to give to any student both the theoretical training and the experience requisite for the successful engineer. What part then in the work of producing the engineer should the school undertake? Experience, as we understand the term, must be acquired in large part outside the school; the engineering college has neither the time nor can it have the facilities for imparting experience to the extent, and in the fashion, in which it is necessary for the thoroughly successful practitioner in engineering. The school should largely, if not entirely, avoid that part in the preparation of an engineer which can as well be accomplished outside the school. It should aim to do for the pupil those things necessary to him which he can secure, either not at all or with extreme difficulty outside the school.

The material furnished in the shape of pupils varies in different cases as to the amount and the thoroughness of work already put upon it, but the product which the engineering college should turn out as graduates is young men who shall have (1) a foundation training in theory applying to engineering, which shall be at all events sound and effective as far as it goes, and if possible extensive enough to meet all reasonable demands in the future at the hands of those requiring the services of engineers; (2) sufficient familiarity with the applications of theory to practice to make the former of direct practical value. These two constitute a foundation or preparation sufficient to combine with experience in making an engineer, in so far as training in contradistinction from talent or genius can make an engineer. There should be added, however, to secure the best results, (3) sufficient experience, or contact with the apparatus, processes and materials of engineering to assure the securing of positions in which the necessary additional experience can be secured to supplement the training in theory already acquired; (4) some knowledge of principles, processes and methods used in connection with engineering enterprises, so that breadth, as well as knowledge of detail in that business may be easily acquired; and (5) a general liberality of education, such as to allow a proper conception to be entertained as to the relations which any large enterprises connected with engineering bear to the political and social conditions existing in the world.

For the substantial foundation of theoretical training, which is the first requisite of the engineering course, the text-book is well-nigh a necessity. Much of this work is mathematical. Nearly all of it must be in its quality exact. The text-book tends to exactness while the contrary is true of the lecture. A failure of exactness in the latter may be chargeable to the lecturer, to the student or to both. It cannot be certain that the lecturer will be exact in what he gives; it is quite certain that the student will often be inexact in what he acquires from the lecturer. So far as the subject requires the mastering of principles or the acquisition of methods of reasoning, recurrence must often be had again and again to the statements made, possibly in order merely to understand them, certainly in order to acquire a grasp sufficient for demonstration or for incidental use in later operations. Furthermore, a lecture is unsatisfactory unless directly, readily and clearly understood. A text-book, on the contrary, especially in mathematics, should often state facts or propositions in such sequence that a definite effort is absolutely required on the part of the student in order to reconcile a statement with that which precedes. In many mathematical subjects the best text-book is the one which, in passing from one step to the next, leaves a gap sufficient to demand substantial work from the student, but which is graded carefully enough so that each step is readily possible. A student grows strong by exercise, by the work he does himself, not by the amount of material brought before him, nor by the efforts of his teacher. A common error in teaching, from the primary school up, is for the teacher to do overmuch of the work. The boy who is carefully carried over the stepping stones which he should cross himself, is ill fitted for the task of making his way through the hurdle-race of life. It is to a considerable extent true that necessity for individual work on the part of the student is the measure of the teacher's success, and failure definitely to require such work in a course such as civil or mechanical engineering will be fatal to the strength and success of such a course.

At an earlier meeting of the Society it was stated that "In pure mathematics the text-book is more important than the teacher." Without endorsing the proposition in that form, it is certainly true that with a good text-book an ambitious and able student will prosper either with a very good or with a very poor teacher. In the latter case, with nothing to hope for from his teacher, he will depend completely on his own resources, and gain tremendously in strength. With a teacher just bad enough to drag him past his difficulties he may be coddled into a state of flabby weakness. The text-book, too, suggests the recitation, and this in turn requires from the student a strict and prompt responsibility to the teacher as to his improvement of his opportunities for study. While it may seem that this ought not to be necessary for students in the Junior or Senior years of the engineering college, yet in the experience of the writer it is a definite necessity in order to secure the best results. We are in this matter forced to act on what is, rather than what ought to be. For many reasons the writer firmly believes the text-book to be the most important of the means to be used in the education of the engineer.

But the text-book is insufficient in itself. While its lessons are food of the best sort, this needs to be made palatable, and for the best results even in teaching theory, the interest of the student must be stimulated. In all teaching, in fact, it is essential that the interest be maintained. Even in athletics it is largely recognized now that formal exercises are in general less effective than are athletic games where interest in the sport renders the work more spontaneous and invigorating. The interest of the student, then, must be maintained. The text-book is ill adapted to maintain it, and lecture, laboratory and design must be made use of, in part to do away with monotony; in part to serve the necessary purpose of connecting theory with practice; and in part to illustrate and to enforce, both by means of repetition and by emphasis, the valuable lessons which the text-book lays down.

The lecture is of exceptional value, in connection with and as a part of the class-room work. A part of the exercise naturally devoted to recitation may be used with advantage to explain points of obscurity, to describe the practical applications of the theoretical work, the dangers of misuse, the precautions necessary in securing data, the standard of precision necessary in measuring or in calculation, or to do whatever else may serve to cause the student to appreciate the matter in hand in its various bearings. The skillful teacher may in such ways so thoroughly vitalize an otherwise dry or almost dead subject as to cause the students, or many of them, to be actuated by a desire to understand the subject, rather than to pursue it simply as a required task.

Design serves a different purpose. Ordinary problems serve to give point to class-room work, and if arranged as they can be, to require from the student something more than the substitution of values in a formula, will demand something of the intellectual exercise which is desired to develop the mental fiber of the student. Work of a similar sort is done most excellently by the exercise in design. Its purpose should be without fail to enforce the theoretical work in which the student has been prepared. It is most desirable that the design should also represent modern practice, and in that way not only connect theory with practice, but also give the student that much of useful knowledge and preparation for the actual practice of his profession; for that can be done for him without the loss of valuable time and opportunity for training. It is important, however, to bear in mind that the controlling factor in the selection of the problem in design should not be the value of the student's result, but rather the quality of the design in introducing again, and thus enforcing the theoretical work previously or contemporaneously undertaken.

Oftentimes an adequate understanding of a proposition comes only from persistent repetition. A principle of mechanics first taught in the course in physics, is repeated in applied mechanics, forms a part of the instruction in a course in bridge work, and finally becomes definitely a part of the student, perhaps only when enforced by an exercise in design. A variation in the amount of design work required of different students having the same amount of text-book work will show its effect in the examination on the latter subject. However much we may think that it ought to be unnecessary, it will not do for us to shut our eyes to the fact that where a definite understanding of theory is necessary, a thorough drill and reiteration of principles is absolutely essential.

Design, then, is valuable in enforcing theory; in connecting theory with practice; in giving to the student something of the experience with the processes and materials of engineering; and in acquiring manual skill in drafting necessary to assure him of employment in positions where there will be opportunity for his experience to be extended after graduation. Design is certainly of great value as one of the methods of teaching engineering.

What is true of design is also true to a large extent of the laboratory as a method of instruction. As a means of fixing and illustrating principles, it is of incalculable importance as an aid to the teaching of theory. In introducing the student to the apparatus and allowing him the use of materials of engineering, and to that extent allowing theory and experience to unite in making him at once to some degree an engineer, its value is considerable. But the laboratory does something more for the student as an educational factor, in that it trains the eye and hand, in addition to the faculties developed by the text-book, and thus largely adds to the all-round development which is necessary to the man who is to have a liberal education in its proper sense. The writer is sufficiently an optimist to believe that the extraordinary development in recent years of the laboratory as a part of the engineering college, is due to its intrinsic merit. It is nevertheless true that the older graduate engineers, the men who have to a large extent advanced the reputations of the institutions they represent, these men had not in any considerable degree the benefit of laboratory instruction. It will not do to shut our eyes to the fact that the laboratory is a menace as well as a boon. Its work is attractive to teacher and student alike. The preparation it constitutes for the immediate usefulness of the graduate is such as to encourage its undue use, not only in the amount of time granted for it, but in the nature of the work accomplished. The laboratory should be used primarily as an indispensable aid to the other work of the school. In so far as its work is carried on either mainly with reference to the practical value of its results (as in research), or in order to impart great facility in manipulation to the students, its value as an element of teaching is largely destroyed, and its influence is dangerous in its tendency to interfere with what ought to be considered the more legitimate work of engineering education. It will be understood, of course, that the field-work of civil engineering is properly regarded as laboratory work.

The memoir, if we may use a word sometimes employed for the purpose, is substantially a form of laboratory work in which the library is the work room, and books on engineering become the pieces of apparatus used, and where a certain subject is assigned, upon which the student shall make his report in writing. The method, by whatever name it may be called, has probably been less used in connection with engineering instruction than with such subjects as history or economics, which are generally more closely connected with literary courses. The method has many points of merit. It is very effective in stimulating the student's interest. It calls for substantial and discriminating work on his part, and for the exercise of mental faculties less often called into play in engineering courses. It makes him familiar in the proper way with the library, with books themselves, materials from which the engineer will find it necessary to acquire much information and instruction. The information he secures may be made valuable to him. As an exercise in English this work has a peculiar advantage from the fact that the substance of the subject will so occupy the student's mind that the form of expression will be sufficiently subordinated to give encouragement to a freedom of style and individuality often liable to be lost where the student is oppressed by the idea that something special in the way of literary effort is expected of him. Variations in detail of the method of teaching by memoir will readily suggest themselves. A reference to a subject in a foreign text-book or periodical will render the exercise one in language to a greater extent than if the article be in our native tongue. The writer has for several years assigned certain subjects to his students who, after preparation for the exercise, take the platform and themselves lecture to the class. If not carried too far, this work is profitable to the lecturer and without material sacrifice to the other students. The memoir is especially well adapted to those institutions where smaller classes are possible.

Thesis might perhaps be included as a method of instruction. Its work, however, comes largely within the lines of methods classified as design, laboratory or memoir. As an element of instruction it has the special merit of developing the spirit of self-dependence in the student to an extent not easily secured in any other way. It is the writer's opinion that the thesis should, however, be used primarily for its teaching value, for its effect on the student's education rather than as a means of gaging the student's ability, or for the purpose of securing results of scientific value. In fact the primary purpose of all teaching should be the development of the pupil rather than to determine the measure of his performance. The examination itself may have more value in requiring a review and demanding faithful attention to duty and in training the student in the ability to work under pressure, than it has as the test of the student's ability and faithfulness.

The lecture, too, deserves a larger place than has previously been given it here in connection with instruction by text-book. Properly used, it may be made a very important factor in the education of the engineer. Carelessly used, it may consume much time with little profit. That it can be used to advantage as compared with text-book work for theoretical instruction, where exact knowledge and understanding is required, the writer does not believe. But it is possible to use it to great advantage in bringing before the student many phases of practical engineering work and methods, in such fashion as to familiarize the student with the many ways in which theoretical considerations enter into the general principles and into many of the details of engineering practice. The principles underlying good, even advanced practice, may be brought to light, and the student in this way acquire directly from his teacher what may properly be called engineering experience; and, what is equally important, he may be so schooled in the process of building his observations of things engineering upon his strong foundation of principles and theory as to be able later to quickly and accurately acquire the true experience and engineering judgment by processes with which he has become familiar in the lecture. Facts observed can be arranged in the mind of the educated engineer in proper order with reference to what he knows is correct in theory, and an application in any case of theory suitable to the existing facts will thus be made to form a most important part of what is called engineering judgment. So far as a lecture is devoted mainly to the mere description of engineering details, its value as a means of instruction is distinctly lessened if not destroyed. It attempts to do what can as well, perhaps better, be done elsewhere, and it is justified, if at all, mainly on the ground of fitting the young man for immediate employment where opportunity for better things awaits him. It hardly allows him to best improve his opportunity for school training.

Where the lecture system is adopted for subjects of considerable importance, five or ten minutes of the time allotted may be used for the student to give written answers to questions presented. The immediate accountability for an understanding of the last lecture will secure from the student a different attitude of interest, and a more definite understanding of the subjects presented.

The lecture may, however, perform another function and be used in many courses somewhat in the way of recreation, of relief from the many severe subjects forming the course. Such a course may be of great value though it attempt no more than to enlarge the horizon, and cultivate the proper point of view from which to observe the bearing of engineering upon large undertakings, and serve the purpose, already stated, of acquiring a proper conception of the relations which any large enterprise connected with engineering bears to the political and social conditions of the country or the world. As an example, a course in railroad management as a part of a strong course in civil engineering may advantageously be conducted by lecture for this purpose.

Different subjects may properly be taught by different methods, and the adoption of the method used in any case may depend in a large degree on the character of the subject, but in some degree on other conditions such as its importance in the general course of which it forms a part. The lecture course which seems well adapted to instruction in railroad management as a broadening element in an otherwise severe course in civil engineering might demand the use of both text-book and memoir if the subject should become one of primary importance in a course to prepare young men directly and especially for railroad operating. The use of different methods may be justified, too, even by the abilities and tastes of the teacher. Some teachers are definitely strong in recitation work and decidedly weak in lecture. Others are admirable lecturers and poor in recitation. It is often a matter of judgment not only as to what subjects shall be treated in a general course, but also as to the way in which the subjects shall be treated. The range of opportunity may be so great that either of several subjects will serve admirably for the purpose of both training and conveying information. The lines in many cases are not rigid. Some latitude may, with great propriety, be granted to allow each instructor to work by that method which allows him to do the most effective work in reaching the student and touching the chord which will most freely respond with effective effort.

While the writer believes that teaching by text-book should form the back-bone of a course in engineering, he is further convinced that the use of various methods, rather than any one alone, will develop the capacity of the students in various directions. One method will demand the use of certain faculties and another method is calculated to develop latent powers, and together these will result in securing breadth as well as depth of training.

Similar results are known to follow from the contact of pupil with various teachers. Among the most effective factors in education in many cases is the inspiration which the student derives from an able teacher. It is also true that no single teacher brings out the best there is from every student, nor does any teacher act with equal efficiency upon the various qualities of mind and habit of any student.

It follows, then, that the best results are secured when there are a variety of studies, when there are several methods of presentation used, and when the student is brought in contact with a number of teachers. By such means the necessary interest is maintained, and a broader and more perfect development of mind is assured than is possible under a single method or under any one teacher. Among certain advantages which the larger colleges of engineering possess over the smaller, this should not be underestimated.

Discussion.

Professor Mees expressed himself as thoroughly in accord with the author's views, but he thought that one point in connection with the subject of laboratory work might be emphasized a little more. He agreed with the author that a great deal of the laboratory work that was done was useless. The laboratory could be employed with beneficial results in connection with the lecture room, but in institutions having large classes this became almost impossible. In such cases, the apparatus was often set up for the student and the work done by the instructor or else the student did little more than to pull the string. In the speaker's opinion that kind of laboratory work was vicious and worse than a waste of time. Again, he thought it foolish that students should be required to perform three, four, or five hundred identical experiments. One of the best forms of laboratory work was to give the student some simple problem, well within his range, and tell him to go to work to solve it. Even though the student did nothing more than to work upon that one problem he would be acquiring knowledge which in his future career would be most valuable to him. In conclusion, the speaker wished to thank Professor Allen for his excellent paper, which left so little to be said.

Professor Williston said that the last speaker had touched upon a point which had impressed him as being of particular importance. In the laboratory work which had just been described, it was assumed that education was a process of development from within, and all the exercises were arranged with a view to stimulating the student to do something of his own accord—to think and act for himself—instead of having him go through certain motions, become familiar with certain operations, and learn to do certain tasks. The speaker thought that the same idea, so well expressed with regard to laboratory work, would apply with equal force to all the four years of a college training; to text-book work; to lecture; and to college work in general. Everything that was asked of the student should be carefully planned so as to develop in him spontaneity and self-activity and that we should get farther away from the old idea, that the mind was like a box to be filled with facts and formulas which might be drawn upon at some future time. The essential purpose should be to help the student's mind to grow and to make him a larger and broader man, rather than to fill his mind with information.

Professor McNair said that while he thought the paper was full of good suggestions, there was perhaps no one present who did not feel that some one of the points might have been more strongly emphasized.

He, himself, would have liked to have had a little more stress laid upon the lack of homogeneity in the classes with which the teacher had to deal. He thought that the earnest teacher would frequently vary his methods according to the apparent need of the particular class, using the lecture to supplement the text-book, or laying the text-book aside and using the lecture altogether for a time. He would attempt to learn what the condition of the class before him required; that what might be necessary for one class this year might not be best for another class next year, even in the same subject; that two succeeding classes might require very different treatment. In the speaker's opinion no teacher should commit himself either to the text-book or to the lecture, or in fact to any other single method.

Professor Caldwell said that the comparison between the lecture and the recitation method interested him particularly and that he believed it was a subject which was not given sufficient consideration by many teachers. It was doubtless more interesting to the average teacher to lecture to a class than to ask questions upon the subject from a text-book, and one feature in favor of the lecture was its value to the student in acquiring the ability of keeping notes systematically. The speaker said that after leaving college a great deal of information had to be obtained by word of mouth and recorded in that way, and the student should, therefore, have practice in taking notes and keeping them in good shape for future reference. In connection with text-book work, that matter was likely to be overlooked. The speaker had used the seminary method for two years and had been very much pleased with the results that had been obtained by it.

Professor Hatt agreed heartily with the views expressed by Professor Allen. He believed that those more especially interested in class-room work were apt to look with some suspicion on the attractions of laboratory work. He believed too that it was necessary to guard against undue development of the latter. The speaker had been in the habit of questioning students who had come back to college after three or four years in practice to take the examinations for post-graduate degrees. He had taken pains to ask what part of the college course each thought had been most beneficial to him, and the answer had always been that it was the theoretical work in mechanics, thermo-dynamics, physics and so on. In most instances these were men who had not taken much interest in theoretical work before they had gone into practice. He urged the necessity for the same interplay between laboratory and class-room work in technical subjects as existed, for example, in the teaching of physics.

Professor Allen, in closing the discussion, desired to express to those who had participated in the same, his appreciation and thanks for the additional light which they had thrown upon the subject. Nearly all of the points suggested by the speakers he would have been glad to have had brought to his notice early enough to have allowed their incorporation in his paper.

By Correspondence.

Professor Dugald C. Jackson: During the course of a decade we have rapidly advanced in the engineering schools toward an appreciation of the proper relations of engineering as viewed by the magnificent men who may be credited with founding the profession. Possibly the conception of engineering which they held is fairly illustrated in Tredgold's good old definition, "Engineering is directing the sources of power in nature to the use and convenience of man." The engineer who follows the profession covered by this wide-embracing definition must be a man of science, as well as a man of the world and of business, and a man who is well acquainted with the trend of human civilization and human aspiration. To make such a man requires years of the most careful training. Faraday said that it requires twenty years of work to make a man in physical science, the intervening period being one of infancy. How much more effort must be expended to make not only a man in physical science, but a man in business and a man in sociology as well!

Such men were the early great engineers, and their far-sightedness is illustrated in the present consummation of that remark of Joule, "I can scarcely doubt that electromagnetism will eventually be substituted for steam in propelling machinery." How far Joule's views in the future have been fulfilled, we all know. What proportion of the college-bred engineer apprentices of this day are inoculated with the same broad spirit of far-sightedness we cannot tell, but the writer fears the proportion would grieve us were it known. We are a people whose individuals prefer to command great works than to inscribe a Greek verse, and with this the writer has full sympathy, but the force of our college training is often broken by too much bending toward the applicability of the methods of teaching and the subjects taught to the immediate earning of dollars by the graduates, while the effect upon their later development into men of power is forgotten.

The abstract of Professor Allen's paper shows so just an appreciation of various requirements in engineering college courses, that the writer overcomes a hesitancy to enter a discussion where there may justly be many conflicting opinions regarding the merits of the methods presented. The writer is embarrassed somewhat by the fact that his views of a true engineering college course are decided and somewhat in opposition to the practice of some colleges of high repute; and while he feels entire confidence in his methods, which are based upon the foundation of engineering experience, and do not differ fundamentally from those used in several of the foremost engineering schools, yet he accords his colleagues of other colleges who take opposing views full credit for equal desire to do right. To the writer's mind, an 'information course,' so-called, must be superficial and so be injurious to a college student. "It is not book-learning young men need, nor instruction about this or that," so much as, "a stiffening of the vertebræ which will cause them to be loyal to a trust, to act promptly, concentrate their energies, do the thing required"—and to do it of their own initiative, using their own powers of thought. The student must be inspired and taught to work for himself in the manner used by George Stephenson when instructing his assistants and pupils. "Learn for yourselves," said he, "think for yourselves, make yourselves masters of principles, persevere, be industrious, and there is then no fear of your success." In the writer's opinion the criterion of success of a college course in engineering which is frequently applied, especially in the West—that is, a judgment based upon the rate of pay received by the men immediately upon leaving college—is entirely erroneous, though the criterion seems to be endorsed at some of our schools of engineering.

Our college graduates should properly be looked upon as apprentices in the engineering profession. They should become *thinkers* in college, capable of usefully applying their scientific knowledge therein obtained; and should be expected to become engineers through experience in applications of knowledge in a manner which may only be gained in apprenticeship in the industries, similar to the office and hospital apprenticeships of the budding young lawyers or doctors. Four years is but a small part of Faraday's period required "to make a man" in the physical sciences, and in so short a period only the foundations for our man can be laid. "There is a great difference between reading and study; or between the indolent reception of knowledge without labor, and that effort of mind which is always necessary in order to secure an important truth and make it fully our own," said Joseph Henry; and the college course in engineering should be bent toward such a complete and true presentation of thorough science and truth that the student is incited to permanently secure it for himself and make it fully his own, and it may then be put to valuable use in future practice. The writer would gladly be judged of the success of his teaching by the success attained by his students after years of practice, but let no judgment be passed upon the basis of wages received during the year after graduation. Our engineering college teaching may be properly condemned if it does not plant the methods of thought that will grow more valuable with the years, and indeed become most valuable only after a mature development.

The engineering course should not be too formal or limited to the didactic methods used of old in the instruction in classics. Professor Tait speaks the views of the scientist when he says: "It is better to have a rough climb (even cutting one's steps here and there) than to ascend the dreary monotony of a marble staircase or a well-made ladder. Royal roads to knowledge reach only the particular locality aimed at, and there are no views by the way. *It is not on them that pioneers are trained for the exploration of unknown regions.*" The truth of this proposition has been discovered of late years by even the most ardent classicists, and those of us who are untrammeled by traditions and are aided by the influence and example of the old engineers should most fully appreciate this fine precept of a great mathematician and philosopher.

To the engineering student in college, the laboratory is of inestimable value. In it he can learn the true relations between science pure and science applied. He can learn to reason truly from cause to effect. His mind can be developed less trammeled than in the class room, and the inspiration to independent thought may be more readily given deep root. "Every branch of engineering is becoming rooted more firmly to the scientific bed-rock upon which it rests," and the engineer must be a man of scientific instincts, scientific thought, and scientific methods, besides being a man of business. He must have learned with the scientist that the price of success is constant, concentrated effort. All this can be taught better in the laboratory than in the class room. Said Mr. Hart in the *Atlantic Monthly* not long since, "Genius is nine parts character. The prize is to him who dares, not merely to him who can." *In the laboratory the student may be inspired to dare.* "No printed page can do the work of heart and hand and speaking voice," and student and instructor may meet more nearly upon an even plane in the laboratory than in the class room. A spirit of indifference which may readily be bred in the class room, and which is ruinous to success and happiness in life, cannot exist in the laboratory that is properly administered.

It must not be thought that I do not give adequate place to the class-room lecture and the text-book work; the laboratory work should be carried on in unison with and fortify the work of the class-room. A power may be had through it which cannot be gained in the more formal meetings, and I would have at least one-half of the time consumed by students in the study of applied science or engineering spent in properly supervised laboratories. The work in the laboratories should be of a strictly scientific character. The application of the forces of nature to the use and welfare of man requires a profound knowledge of science and scientific methods. And every well-trained engineer must hold the greatest sympathy with pure science in every branch, for he clearly understands that ultimately it will all come as grist to his mill.

In this nation the industrial pursuits are engineering pursuits and in the present juncture—after the laws of mechanics—the laws of electricity seem to be of the most importance to the industrial engineer. I would therefore give great weight and strength to the electrical laboratories. While the subjects particularly taught are not of so much importance as the effect upon the student's powers ("Victory is for the people who see things as they are without illusion, who do not take phrases for facts"), the well-planned laboratory courses in applied electricity serve excellently to give that clear sight of "things as they are" which is essential to success.

The electrical laboratories in the various colleges have as a whole been handled by men of great enthusiasm and enterprise, and for that reason, possibly, better results have come from instruction in the electrical laboratories than in some other branches. But even upon an equal basis of enthusiasm and enterprise in the instructors, there is a wider variety and livelier interest in the problems that may be set before the student in the electrical laboratories, and hence the electrical laboratories, if properly administered, cannot fail to be of unusual advantage.

THE ENGINEERING EDUCATIONAL VALUE OF A REFRIGERATING PLANT.

BY WM. T. MAGRUDER,

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The value of a piece of educational apparatus is proportional to the amount of instruction and experience which it can aid in imparting to the student, and to the use which can be made of it for advancing and increasing knowledge; or, in a word, to the amount of knowledge which it can disseminate and add to the world's stock. In the early days of technical education, a few pieces of costly apparatus and a lot of makeshifts constituted the equipment. The small commercial engine then answered for instruction in steam engineering. Now, the elaborate and more expensive types of high-pressure, triple-expansion, condensing engines are desired wherewith to impart and illustrate the nicer points of theory and practice. Then we had nothing in the way of refrigeration machinery, and the gas engine was but a foreign toy, a French novelty. Since that day, science has advanced and commercial needs have pushed the practical applications of science so rapidly that we are to-day in the subject of refrigeration where we were in steam engineering twenty or twenty-five years ago. Large refrigerating plants are to be found in the breweries, abattoirs and ice-factories of all our cities, and smaller ones are to be found in the hotels in many cities. They are, however, so connected up with other machinery, that it is extremely seldom that a performance test can be made on account of the difficulty in disconnecting the refrigerating from the heating, pumping and power systems of the plant. Ordinarily a capacity test is more than sufficient; the rated capacity is almost invariably obtained; and the results as to cheapness and ease of manipulation are so satisfactory that the purchaser goes no further in his tests. Scientific tests are rarely made except by enthusiastic experts.

Within the past few years, however, the dairy and creamery industry of the country has found that mechanical refrigeration was much more satisfactory, efficient and economical than was the use of ice, even in our more northern states where a plentiful and cheap supply of ice can be easily gathered every winter, and hence there has been a demand for small machines of from four to ten tons capacity. Here again commerce has pushed science, and so the agricultural colleges of our state universities are beginning to introduce the use of the ammonia compression system of mechanical refrigeration. Here then is a chance for the engineering colleague of the professor of agriculture to adapt himself to circumstances most favorable, and, accepting the good fortune of his agricultural brother as his own, obtain permission to use the full-sized commercial refrigerating plant-boiler, engine, pump, injector, ammonia compressor, condenser, expansion valves and refrigerating coils—as engineering laboratory apparatus; make provision in the installation of the plant for the necessary thermometer cups, ammonia indicator and metering devices; and be prepared to make more or less complete and scientific tests of the same at but a small expenditure for apparatus of the limited funds of his department. There need be no conflict as to times, provided the engineer and his students can work at nights. The agriculturist should and will be very thankful for the data obtainable which will assist him in decreasing his costs and increasing his profits.

Within the past two years the Ohio State University has passed through the above history, and it is thought that our experience may be helpful to some of our fellow-professors elsewhere when their turn may come. Much credit is due and is hereby accorded to Professor T. F. Hunt, Dean of the College of Agriculture, for his skill and foresight in the installation of this plant; and the thanks of the department of Mechanical Engineering are tendered him for the opportunities offered, permitted and embraced.

The refrigerating and power plant of the dairy laboratory of the College of Agriculture consists of one 40-inch by 12-foot horizontal, return-tubular boiler containing thirty tubes 3½ inches in diameter. The boiler is supplied with water by an injector. Knowing the quality of the steam at the injector and its temperature, and the temperature and amount of water delivered, and the temperature of the delivery, the theoretical quantity of steam consumed may be determined, and the error corrected for by comparison with tests on the same injector in the regular injector testing apparatus in the laboratory. The calorific value of the coal was determined by a Mahler calorimeter in the department of metallurgy.

To the boiler is connected a high speed automatic cut-off engine which is used for power purposes and which can be entirely disconnected during tests of the refrigerating plant. The boiler supplies steam to a 7 x 10, two-hundred revolution per minute, throttling engine. The engine, by a 6-inch belt from its 20-inch belt pulley, drives a 6 x 7, double-acting, six-ton, horizontal, ammonia compressor at one hundred revolutions per minute. The refrigerating machinery was made and installed by the A. H. Barber Manufacturing Company, of Chicago. The linear clearance of the compressor is one thirty-second-inch. The compressed ammonia, passing through the oil separator, is condensed in an open submerged condenser containing 130.9 square feet of cooling surface in 1-inch pipes. The condensed and liquefied ammonia is collected in a receiver below the condenser whence it passes through a special Worthington ammonia meter on its way to the expansion valves in Townshend Hall. The refrigerating surface is distributed as follows: 72.1 square feet in the cold room, 67 square feet in the water cooling coils and 146.6 square feet in the cheese-curing room.

In testing the plant, the American Society of Mechanical Engineers' code for testing boilers was followed; flue gases were not analyzed, but their temperature and suction were taken. Indicator cards were taken from the engine every ten minutes and the indicated horse power of the engine so determined. The quality of the steam was taken at the engine and at the injector by Barrus calorimeters and the losses by same deducted. The engine was charged with all the steam fed by the injector to the boiler less the calculated amount of steam used by the injector, and less the amounts wasted by the two Barrus calorimeters. All other connections had been disconnected or capped.

Indicator cards were taken every ten minutes on the ammonia compressor, using a Crosby ammonia indicator. For the best working of the compressor the clearance must be a minimum, hence the indicator connections must be as short as possible. The connections are $\frac{1}{8}$-inch diameter in the cylinder, and the indicator straight cock should be screwed directly into the cylinder, and its opening made not over $\frac{1}{4}$-inch diameter. There should be absolutely no copper alloys used in any place where ammonia or ammonia fumes can get to them. Even the outside washer on the plug of the ammonia indicator cock was eaten away so that it became brittle and broke. This is a point which people know theoretically and which is in all the books on the subject, but which no less than three makers of ammonia machinery and apparatus forgot when they shipped to us goods made of brass and especially ordered and made to be used with ammonia. In measuring the amount of ammonia circulated, a special five-eighth-inch, extra heavy, cast-iron and steel, Worthington meter with special small plungers so designed as to register quantities as small as one gallon per minute was used. The meter was calibrated in the laboratory when delivering the same quantities of water at the same pressures as it was used for with ammonia.

Two methods of computing the ammonia from the indicator cards, and also one method from the heat taken up by the condenser, were used, but did not at all agree. Temperatures were measured with Henry J. Green thermometers before and after passing the compressor, the condenser, the three expansion valves and on leaving the three sets of refrigerating coils. The condensing and jacket waters were weighed, and their temperatures before and after were taken. The thermometers were immersed in mercury placed in solid steel thermometer cups made with walls one-sixteenth inch thick screwed into ordinary heavy cast-iron fittings, chiefly Y's. So far we have had no accidents and have no reason to regret that we did not put in special ammonia fittings at ten to twenty times the cost of ordinary cast iron fittings.

The methods of calculating the results are the same as are given in Wood's Thermodynamics and in the *Transactions of the American Society of Mechanical Engineers* and need not be repeated here.

As an experimental engineering laboratory exercise and as a "test of plant," the test of an ammonia refrigerating plant is complete, containing as it does the direct and reversed cycles of energy, and the use of the heat so dissipated in the condenser in absorbing more heat in the refrigerating coils. Furthermore, it offers a practical illustration which seems to be quite easily grasped by the student, of what is meant by the liquid, vaporous and gaseous conditions of a substance. A student who can direct, or can make a complete test of a refrigerating plant, and can calculate all the results, has a good working grasp of practical thermodynamics. As a field of engineering research, the use of ammonia refrigerating machinery opens up new problems, and new chances for original theses. As a chapter in thermodynamics, it forms the capstone, knits the various preceding chapters into one harmonious whole and provides ample illustrations and mathematical exercises. As a chapter in applied physics, it covers a range of from —30° F. to the temperature of the furnace gases, specific gravities of gases and liquids, the anhydrous condition of the ammonia, and the more difficult subject of specific heats.

For these reasons, therefore, the use of such apparatus is recommended to the mechanical engineering members of the Society.

AN APPRENTICE SYSTEM IN COLLEGE SHOPS.

BY OZNI P. HOOD,

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The title of this paper names an expedient used to increase the usefulness and efficiency of a manual arts shop in a State Agricultural and Mechanical College. I wish to give briefly the opinions which led me to the trial of an apprentice system, to note some results, and, while expressing a belief that the plan I suggest is worthy a trial in many places, to deny at once any universal applicability.

The ideals of the shop in question were near those of the Worcester Polytechnic Institute, but lacked the features of commercial competition. It was believed that shops without the life and movement of a real, producing organization lacked a most essential atmosphere and that a sacrifice of time and money was warranted in providing a variety of work, continuous running, and a life not dependent upon the presence of students. It is usually agreed that a small commercial shop, because of its variety of work and continual call for ingenuity, is a better place for training than the highly specialized manufacturing plant. A rigid adherence to a system of problems throughout a shop course, unaccompanied by any other constructive work comes entirely too near furnishing the limited field of view of the manufacturing plant with its unending sameness of conditions and results. It was considered by no means desirable to dispense with the advantage of a carefully graded plan of work. While a systematized course formed the basis of all instruction, it was desired, whenever possible, to substitute for set problems some work of a similar grade taken from a variety of ever-changing practical work. When such work was not available, recourse was had to the stock problems which were freely used early in the courses but seldom later.

Such a plan requires a considerable variety of useful building. The expansion of a department and its coöperation with other college interests will usually furnish sufficient opportunity. Those who have tried to build machines in college shops have felt the need of some means of finishing those parts beyond the reach of student skill or requiring much repetition, or labor, at a time when that of students is not available. It is this need which furnishes one of the greatest objections to the policy of building things in such shops. If the need is met by departing from true ideals of instruction, the system becomes vicious and the shop fails to furnish its greatest opportunity.

If machines are to be built, the problems furnished by each design should be graded. They should be given to students in a reasonable order as to instructive value and requisite skill. Such grading and sequence is not difficult during the early part of construction when there is a great variety of choice, but becomes serious as the work progresses. The easy and well graded part of the work is soon complete and one is left with portions unsuited to the skill or needs of the student. By supplying a considerable variety of construction, work of a suitable grade may be found at any time; but with variety comes increased difficulty in bringing to a finish anything without help, at the right time, more skillful than that of students. Again, a shop whose only life is that furnished by the presence of students and whose grade of work is that established by the average student ability does not furnish the best conditions for growth. Students lack the opportunity of measuring themselves against those more skillful, and obtain distorted opinions of their own ability. They lack opportunity for observing the numberless methods and manners of real shop-life, the real capacity of tools, the handling of men, the attitude of employees, foremen and other officers. To meet these various difficulties would require a body of more skillful workers continuously employed, furthering work not dependent upon student habits, yet in entire sympathy with them.

College shops do not escape that mark of individuality common to all shops, when judged by the average grade of output, the design, finish, ingenuity and usefulness of its material product. The average attainment is limited by the grade of students and the ideals presented. All students are affected by this average. Any plan which betters the grade of work for which students are even partly responsible, helps to supply a desirable condition. This too requires more skillful workers coöperating with students. The presence in the shop from year to year of some unfinished project begun by previous classes has a depressing influence on students. It seems very desirable when once a project is started to finish it with certain movement, and in time to give those who share in its building a share in the pleasure of completion. The several needs so far enumerated are : First, a desirable variety of work to replace fixed problems, which will require some things that should not be expected of students. Second, a shop life and movement not dependent entirely upon students. Third, the presence of more skillful workers to raise the average grade of work in sight. Fourth, means whereby projects shall not become ancient monuments of incompleteness.

These needs show the desirability of employing men in the usual way, selected for their skill and for their ability to work harmoniously with a body of students. This method I should prefer, but the usual college can not afford it. The employment of one or two journeymen is hardly sufficient to establish the desired movement and atmosphere in a shop training from one to three hundred students. With paid help a State College would have difficulty in quietly disposing of any output, sold to reduce the expense.

Another line of thought helped to suggest the expedient tried. A manufacturer tries to run his plant full time in order to produce a maximum output. There are many college shops provided by the state which work on less than half time. An elaborate equipment may lie idle a portion of each day or a portion of the year. The scheme of class hours, or instruction periods, may make it impossible to use the full capacity of the plant for its prime purpose. While: "They also serve who only stand and wait," it seems a pity that these shops dedicated to instruction should for any cause find lack of constant usefulness. If the legitimate use of the shop requires that it lie idle for a time, or that its use in any other way is incompatible with its prime function in the engineering course, then there is excuse for this partial employment. I am not convinced of the necessity. There are many young men desiring such opportunities as the shop could afford—men unable to take a college course. These would be glad to give their labor in return for shop opportunities and this labor can be made of sufficient service to warrant its use.

A call for apprentices was made through the college paper. Each apprentice was to be over eighteen years of age, acceptable to the Superintendent, and was to work not less than thirty hours per week for forty continuous weeks. He was to work in the foundry, blacksmith shop and machine shop, as required, to receive no compensation and to be subject to discharge at any time by the Superintendent.

From many applicants, some of whom were college graduates, ten men were selected. Their age was nearer twenty than eighteen. Most of them had been college students at some time, but were unable or unwilling to continue. The average ability was about that of second-year college men.

At this time there were about three hundred students in the various shops, but only about thirty in the machine shop. The instruction periods were such that the metal shops had been employed but five afternoons in the week, leaving each morning and a full holiday unused. The apprentices were assigned to these periods. During the regular class hours, apprentices were employed only as there was room, but it soon transpired that they were working most of the time. They were used in the foundry, making castings for regular work, and many changes and small repairs were made by their help. They soon possessed more skill than the average student and were working on machine parts together with students.

It then became possible to build simple machines in short order and greatly increase the variety of work on hand. The general movement of the shop became a number of paces faster. Jobs that had been on hand too long were finished. The temptation to employ students on work of questionable instructive value was removed. Without doing violence to ideals, such work could be given apprentices. The effect on student work was pronounced. There was a healthy rivalry with the apprentices, more perhaps than if journeymen had been employed.

At the end of the year, superintendent, foreman, and instructors felt that the needs enumerated had been partly met by the apprentice system. The foreman preferred that the system be continued, for while it required his time in one way, it reduced his difficulties in others and made the shop instruction more efficient. The material output for the year was of a better quality. Its cash value to the college paid for any outlay chargeable to the apprentices. The system had not interfered in any way with the regular work of the shops, but had been a decided benefit directly and indirectly. The shops were employed the full day in training young men in the industrial arts. Most of the apprentices preferred to stay a second year. Professor J. D. Harper has had charge of the work since September, 1898, and, in expressing unqualified approval of the system, has extended it. Apprentices now receive some instruction in drawing. There is a pressure of excellent material to select from. The better trained and more skillful are being used as student assistants.

I know of no other place devoted to instruction where young men are given so full an opportunity to enter as apprentices a well equipped shop as at the Kansas State Agricultural College. As the system seems to be of mutual benefit to the regular work, to the department financially, and to the apprentices employed, there is reason to believe the system may be useful elsewhere.

DISCUSSION.

PROFESSOR CALDWELL wished to ask Professor Hood for a little more definite information as to the class of men these apprentices were.

PROFESSOR HOOD replied that the men had come originally, for the most part, from farms, with the earnest desire to get into mechanical pursuits. Probably half of them had previously been in railroad or other shops. Among the ten apprentices, seven had been students in college, who, either from lack of funds, or lack of ability, had given up their college courses to go into shop work. They were altogether a much better class of men than the term apprentice usually brought to mind and rather of the college-student stamp.

PROFESSOR ROBINSON remarked that he himself had been through an apprenticeship, as well as through a college course, and he thought that in teaching shop-work, it was advisable to divide the work into two general classes, namely, rough work and finished work. The student should first be instructed in rough dressing and then the same piece might be turned over to a second man for the tool dressing, the filing and finishing. The first man should get the piece true in the rough, and the second man should do the fine finishing of the surface. Thus every man, before leaving college, would become proficient in both classes of work.

Prof. Aldrich wished to inquire as to the class of work that the author set for these apprentices. In the mechanical shops of almost all educational institutions, after the installation had been completed, the only other work possible was in the form of exercises, *i. e.*, project-work, or regular manufacturing work. The speaker wished to inquire further whether under this system the apprentices were carried through a system of exercises; or a combination of exercises and manufacturing work; or whether it was entirely manufacturing work. He thought that several new and admirable points had been brought out in the paper. However, while the term "apprentice-system" had a shop sound, such work as here outlined did not really take the place of a manufacturing apprenticeship under which the apprentice was regularly indentured for a term of years. Continuing, the speaker referred to the increasing difficulty of students finding places as special apprentices during summer vacations. The fact was doubtless generally recognized, that if it were possible to employ in some satisfactory way the college shops and laboratories throughout the four quarters of the year, it would be a distinct gain to the student and to the college alike.

Prof. Hood said in reply that his own shop experience probably caused him to look at the shop in a different way from some others; that the idea of letting a shop lie idle for certain periods was rather repulsive to him. His own shop was always run twelve months in the year, but the work was not confined to instruction. The work in summer consisted of repairing, making apparatus, and general provision for the future. To answer the question as to what was offered the young men who were received as apprentices, that might be put in the single word "opportunity." They were not put through graded courses; nor were they given problems to work out. Institutions devoted to education could not fail to afford opportunities, and rich ones, to the student who came with the understanding that he was simply to take what he could get.

Prof. Waldo desired to call attention to what seemed to him a very important bearing of this paper, in that it suggested a solution of the vexed question as to what should be done in the way of a technical education which partakes largely of the character of a trades-school education. It appeared that Prof. Hood had found a way by which an intermediate form of technical instruction might be given in our existing institutions without detriment to the institutions themselves, and to the great benefit of a large class of intelligent workmen who are ambitious to rise, but have neither the time nor the money for an extended technical course of study.

ENGINEERING EDUCATION AND EXPANSION.

BY WM. S. ALDRICH,

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It has frequently been stated, and with particular reference to state colleges and universities, that it is the first duty of the American engineering educator to provide such technical courses of instruction as shall best prepare the engineering graduate to develop such arts and industries as are found at the time within the borders of his own state or territory. That which has been accomplished in pursuance of this policy since the opening of the Military and Naval Academies and the establishment of private and state schools, from the Rensselaer to the latest endowed polytechnic, is now matter of history.

The internal improvements inaugurated in this country by Washington's surveys but await a similar initiative in foreign fields. American engineers have so developed our country, and opened up its natural resources, as to show clearly the need of and to stimulate to similar work in many other lands. What they have done at home remains to be done abroad. It must be carried out some time, by some trained body of equally resourceful engineers. Shall we go in and possess these fields of engineering development?

The present demand for engineering talent abroad is not confined to any one branch of the profession. In opening up mines or starting manufactures; in building roads and canals; in constructing public or private works; in the improvement of rivers and harbors, or in the sanitation of cities; in the extension of telegraph and telephone systems; in the development of transportation facilities, by rail or by water; in the utilization of the resources and forces of nature; in each and in all of these, and in many kindred fields of engineering work, there is an ever widening opportunity for young American engineers to seize if they will prepare themselves for it.

To-day the trained engineer is abroad in other lands as well as in his own, representing American industries, selling American manufactured products, promoting the expansion of our trade. He is installing, operating and managing American machinery in many foreign establishments. He is examining water powers, fuel supplies, timber lands; prospecting valuable mineral lands; and gathering general and technical information for the use of home capitalists. He is searching the world's fields of raw materials, investigating their properties and ascertaining the economics of production for home manufacturers.

In these and in many other ways the profession of engineering is feeling the stimulus of the commercial awakening. The class of work which it can perform is quite as essential as the more direct expansion of our foreign trade, that the mills and factories at home may be kept busy. Each class of work will healthfully react on the other. Where American engineers go to develop the resources or industries of a country, American goods follow. Where American goods are introduced, the development of the natural resources and of local industries will follow as a matter of course. From the standpoint of finding a market for our goods, and a field of work for our young men, it is difficult to say which is the more important—the expansion of trade, or the development of engineering work abroad.

With respect to engineering education, there can, however, be no longer any room for doubt. Such an education must now fit young men to take some intelligent part in the development and utilization of natural forces and resources, wherever found, to engage in the organization and execution of engineering work and works in whatever country of the globe such opportunities may be presented. We should find a foreign field for our engineering graduates quite as much as a foreign market for our goods. Only in this way can we hope to postpone indefinitely another evil day of panicky times, lost confidence, lack of work and an overstocked market.

Whether it will hasten our national downfall or inure to the perpetuity of our national life, we are now committed to new policies of international diplomacy. Foremost among these are such as concern the development of our trade relations abroad for the continuance of prosperity at home. If we are to maintain our hard-earned reputation for successfully meeting each exigency as it arises, for making moves in business and engineering developments that awe the world, for doing the right thing at the right time, then our duty is clear.

Communities, states and nations, are now looking to engineers probably more than to any other class of trained professional men, to secure that dominion over the forces and resources of nature that shall lead to a healthier, happier life from the standpoint of its natural environment. If the sphere of influence of American engineers is to be extended to other people than those within our immediate borders, it will be necessary to make the most thorough study of the conditions surrounding such engineering developments. The sanitary work of American engineers in tropical countries points to at least one direction in which a large amount of engineering work awaits equally capable men.

Engineering education should equally recognize the widening field of the application of science to the development of industry. In some branches of work, at least, the reproach seems destined to become a standing one that we are becoming a nation of skilled mechanics applying to art and industry the sciences whose fundamental truths the old world has established. Very few such truths have Americans established that furnish Europeans with the precedents for engineering practice and construction which are at all comparable to those which foreign scientists and engineers have given to the world at large. All investigations now have a deeper meaning, a wider bearing, a larger field of application.

It is a hopeful sign that engineering graduates are giving their attention in greater numbers to engineering research. Whether in the laboratories of manufacturing establishments, or of educational institutions, they are conferring great benefits on the profession and promoting the advancement of civilization. After graduates have entered upon some more or less remunerative field of labor, they should seriously consider the advisability of dropping such work for at least a year, to pursue special and advanced engineering work and research in some educational institution offering facilities for the same. Only in some such manner can we discharge our bounden duty to the age and add to the sum of human knowledge, that American engineers may establish precedent and not simply follow that of others in the expansion of their respective fields of work, whether at home or abroad.

Our principal foreign competitors have been forging ahead along very clearly defined lines which are now discerned by the results accomplished. They have put forth equal, if not greater, efforts in developing foreign markets as in establishing home trade. In all of this they have shown characteristic thoroughness, painstaking care, and attention to details. Their recent advances in commercial, industrial and technical education have had similar far-reaching results in promoting foreign trade. While many of their young men have sought this object more directly by engaging in commercial pursuits, others have taken up the line of engineering work contemplated in this paper—the development of native resources and of local industries. It is not with commerce and commercial education that we have now to deal so much as with industry and engineering education. In the well-defined limits of the work of this Society, therefore, we may very efficiently aid in the expansion of American trade, the development of industries and the advancement of science.

Foreign trade is a matter of education—education of the manufacturer to the needs of the particular market where his goods are offered for sale; education of the foreign salesman to be the capable and faithful representative of the home concern; education of the foreigner himself to the appreciative point of supplying his newly-created wants by American goods. Commercial travelers of English-speaking countries are less seen abroad than those of any of their competitors. American goods and American manufacturers in particular, are not yet properly represented abroad. Consuls are expected to do much toward introducing home goods in foreign markets, but it is quite clear that no consul can perform such efficient service in that direction as a salesman. Personal visits to foreign markets of trained and educated engineers representing home producers will bring far greater returns, increasing such trade, fostering a wholesome appreciation of American goods, and silencing the cavil of local competition. Moreover, the widespread circulation of trade literature is not sufficient for the introduction of American goods. American engineers should be on the spot, to recommend or require American machinery, for instance, as well as to receive, install and use it in their engineering work abroad. The demand must be created if it does not exist. What engineers, agents and salesmen have done to create wants and to supply them, in this country, must now be extended to include larger areas. For instance, there is an ever-increasing use of all kinds of machinery throughout the world and American manufacturers are quite capable of supplying it through the extension of legitimate business methods found so helpful in this country.

The American engineer abroad has therefore a double duty to perform, being engaged quite as much in a representative capacity as in technical lines of work. He has an enviable opportunity to represent his country and to stand for straightforward business relations, amid the conflicting claims of competing contractors and of manufacturers' agents. Moreover, the ethical relations which he bears to our foreign business constitute a vital link in the chain binding us to world-wide trade interests. Severe criticism has been made of the Yankee's way of doing business when away from home, and especially when exploiting our manufactured products in new markets. It behooves us to train young engineers who will engage in these and allied branches of work with honor and credit to themselves, to the profession and the nation which they at all times represent.

Of all professional men, engineers should have the broadest outlook, the largest views of men and things. This implies a breadth and depth of culture that few of them are getting to-day. If the young engineer is to do anything else than professionally to hew wood and to draw water; if he is to be taken into the councils of corporations and large business enterprises, equally with the lawyer, he must be more of the scholar and the gentleman, more of the man of affairs than he is to-day. The professional status and standing, also, must be very much raised before the American engineer will receive that recognition which is his due in foreign fields, where all scholarly, gentlemanly and business traits count.

Many technical graduates leave college with the most limited views of men and affairs. Finding fairly remunerative employment, they are too easily satisfied. If their employers will not rotate them they should rotate themselves. It is not true in engineering experience, that "a rolling stone gathers no moss." Each new position sought or obtained should give a larger outlook, a higher class of work and more responsible duties. In fact, it is our duty to encourage these young men to consider the wide world as their field, as open to them, and as requiring their energies. There is probably no subject which will take the student outside the pale of his local environment so thoroughly and so satisfactorily as the proper presentation of the fields of engineering work he may come to occupy, in developing the engineering trades and industries at home or abroad. Our graduates have, it is true, in the words of Girard, a knowledge "of facts and things." Without curtailing the one, is it not possible to enlarge the other? We owe it to the students to present at least the essentials of such a world-wide view. Engineering education is in need of the breath of the new life that is now upon us, coupled with that opportunity afforded by the liberal arts courses to scan the horizon of human knowledge and of national growth, to view the world of letters and of life. This want is a common one to all college courses. It has been long felt in the one case. It has been long supplied in the other.

With few rivals on this continent and not caring to become rivals of the old world producers till quite recently, we have not felt the necessity of thorough training in modern languages from the commercial view-point. This deficiency is now so patent that not only have French and German been taken up with a new meaning and purpose, but Spanish also is added to our technical courses. With ever-widening trade relations, such early conveniences will become later necessities for the most expeditious transaction of business abroad.

American engineers must go before, accompany and follow the export of our manufactures. This will necessitate greater attention in technical instruction to the economics of engineering, to the business end of it, and to the commercial aspect of our growing foreign relations. To prepare for wider fields of usefulness abroad will require more thorough training at home. To recognize such demands will react beneficially on engineering education all along the line. It will be a healthful stimulus toward broadening and deepening many of the present technical courses, quite as much in the letter, perhaps, as in the spirit of the movement. The study of commerce, trade, foreign relations and policies, with courses in commercial and international law, and frequent lectures by non-resident specialists, will gather about professional courses that most helpful and broadening instruction demanded by the spirit of the age.

THE CORRESPONDENCE SCHOOL IN TECHNICAL EDUCATION.

BY EDGAR MARBURG,

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At the last annual meeting of the Society, the retiring President, in a thoughtful, far-seeing address,* brought us face to face with certain serious gaps in our educational system. It was shown that, except for insignificant beginnings, here and there, no provision had been made for the specific training of our youth for industrial and commercial pursuits. Our own shortcomings were revealed the more strikingly on the background of Germany's achievements. That nation's phenomenal strides, during the past quarter-century, towards a commanding position in manufactures and in commerce was attributed primarily to its elaborate system of monotechnic and commercial schools, of which, as has been said, no counterpart is to be found in this country.

With us the opinion is yet too widely prevalent that such elementary liberal education as may be had in the grammar, or at most the high school, is all-sufficient for young men destined for the trades and industries, or for commercial life—that the special training peculiar to each particular vocation can be best acquired in actual service. The soundness of this proposition, within limits, is of course conceded. School processes, however carefully perfected, will never cease to have their limitations. Their highest function, after all, is to endow the individual, as well as may be, with the potentialities of after-development. To look for an output of accomplished financiers, business men, artisans, or industrial foremen, straight from the schools, were as preposterous in its way as to expect similar results from our professional departments. On the other hand, barring the great field of common, unskilled labor, there is scarcely a human calling so lowly but that its horizon might be broadened, its inherent dignity developed, its usefulness to society augmented, and the individual interests of its followers immeasurably promoted, if our present loose and narrow courses of apprenticeship were to yield to a well-ordered system of specialized instruction, in which the scientific and practical elements might be suitably blended.

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* Prof. J. B. Johnson, on "A Higher Industrial and Commercial Education as an Essential Condition of our Future Material Prosperity."

That such a change must come about in the United States, as it has in Germany, probably few thoughtful men, at all familiar with the situation, will seriously question. It would betoken small faith in the progressive spirit of our nation to hold otherwise. But while Germany's achievements serve as inspiring object-lessons, the social conditions in this country are so essentially different that the problem presents itself to us in an entirely new phase. Its final solution must be of a kind, not only best adapted to our own peculiar needs, but in best consonance with our school systems, our political and industrial institutions, and the general traditions of our people.

A tremendous amount of agitation will be needed for the successful inauguration of so great a movement. It is to be hoped that the suggestion made last year that this Society should assume the initiative in this matter will not prove to have fallen on barren ground. In the educational campaign which will have to be directed against our trade and commercial organizations, and our legislative bodies, the first concern will be to impress upon them the reality of the need we set ourselves to advocate. To most men of average information the statement that we are falling far short of Germany in preparedness for assuming a leading hand in the world's industrial affairs will come as a revelation, and much scepticism will have to be silenced by argument. Overweening faith in the resourcefulness of this country and in the genius of its people is characteristic of Americanism. But self-confidence, however admirable a trait in nations as in individuals, carries with it the constant danger of merging into self-sufficiency, than which there can be no greater menace to sustained advancement.

While America has time and again triumphed against signal odds, through expedients improvised to suit the means and the occasion, it were a fatal delusion to assume that forces can be created over-night to cope successfully with the gigantic industrial movement to which Germany has lent its best thought and energy for the past three or four decades. Patient, painstaking effort, in the furtherance of a carefully-conceived, broad and enlightened policy, can alone accomplish for our nation what has been attained by like measures for another.

In the meantime there has arisen among us, in the correspondence schools, an educational movement whose remarkable headway must be attributed in no small measure to the existence of those very gaps in our regular system to which reference has been made. Sprung from seemingly insignificant beginnings, some ten years since, its growth, notably during the past two or three years, has been little less than phenomenal. It is a significant fact that the correspondence schools have found their largest following among our technical workers, especially those of our shops and factories. Thus a single institution devoted principally to engineering and the mechanic arts claims a total enrolment of upwards of eighty thousand students, a number four times greater than that of only two years ago. Whatever the merit of the system, these figures bear striking evidence that our craftsmen are keenly alive to the defects in their education, and are grasping eagerly at such opportunities as present themselves. In most cases there exists only the single other alternative of self-instruction. Night-schools in which technical courses are offered, are to be found only in a few of our most populous cities. Besides, their disadvantages are such that they have not come into much favor.

An inquiry as to the probable efficiency of the correspondence system, becomes thus a matter of considerable interest. Is the scheme to be regarded simply as a passing fad, or does it contain the elements of real merit and permanency? Are these schools attracting their immense patronage under false pretenses, or are they engaged in a worthy and successful effort to give their students generous returns on their investment? And, finally, does the general plan give promise of such possibilities that, in its higher development, it may be expected to yield even a fair approach to what has been realized abroad by German methods?

Before attempting to suggest a partial answer to these and similar questions, more especially with reference to the technical correspondence schools, certain considerations relating to such institutions in general deserve to be briefly noticed.

Among our regular seats of learning but two, namely, the University of Chicago and the Illinois Wesleyan University, have entered the field of correspondence teaching. The other institutions engaged in this work were organized and are conducted primarily, if not solely, as money-making enterprises. Their general policy is determined largely by this circumstance. It also serves to render an accurate and searching investigation difficult, if not impossible. The competition for students is already very keen. Statistics of the kind freely published by our regular schools are either withheld on grounds of business expediency, or, where furnished, can not always be accepted with confidence. From their own circulars, it appears that the various schools view each other with the utmost distrust, and open charges of a serious character are not infrequently passed. Their advertising methods in general are not calculated to inspire confidence, or to command respect. Ingenuity is fairly exhausted in the attractive wording of their circulars. Clap-trap schemes of the most transparent nature are resorted to with a view of attracting students. Thus one school quotes its own advertisements as opinions of the press.

A postal card addressed to another with the simple request for a catalogue, elicited the usual pseudo-personal, typewritten circular containing the lines: "We judge, from an intimation discernable in your letter, that you have a will as well as a gift for success." The schools vie with each other in their offers of special inducements for immediate enrolment. Their disinterested anxiety to enlist patrons before the date of an impending advance in tuition fees is quite remarkable. Testimonials and photographs of graduates are prominently paraded. On the other hand, a complete list of students or graduates is not permitted to appear.

In an endeavor at an impartial inquiry, one has constantly to remind himself that these matters have no direct bearing on the subject proper, namely, the intrinsic value of the instruction itself. However, tactics of the kind described tend inevitably to give rise to prejudice and distrust. Nor does it serve to lessen one's scepticism to be informed that even such subjects as music and art can be successfully taught by correspondence. There remains, in fact, scarcely an important field of learning that these schools have not confidently invaded.

That the correspondence scheme throws the doors wide open to charlatanism cannot be denied, nor can it be questioned that the opportunities it offers for illegitimate practices have been freely exploited. Some of these irresponsible concerns have already closed their doors, to the possible gain of their patrons. Others have sprung up in their place whose existence will doubtless prove no less ephemeral. That the general interests of the cause suffer in proportion goes without saying. As with commercial enterprises in general, probably only a few of the fittest are destined to survive. It would seem, however, that the time has come when the financial responsibility of these schools should be made the subject of official inquiry, as in the case of other institutions organized for the receipt of moneys upon the promise of future returns. Without some reasonable guarantee of good faith in the discharge of prospective obligations, the use of the mails should be interdicted.

Referring now to the technical schools in particular, the writer has, by visits and otherwise, made as critical an investigation of their methods as circumstances permitted. Broadly speaking, their scheme of operation is essentially the same. Instruction papers, especially prepared for the purpose, take the place of the usual text-books. These are issued of a size convenient for the pocket. The student is pledged not to allow others to share in their use. The papers on any given subject are furnished collectively in book-form, at the beginning or end of the course. Each instruction paper is accompanied by an examination paper containing the questions which the student is required to answer. These answers are promptly and carefully corrected. The writer has seen ample evidence that at the better schools this important feature receives close, painstaking attention. A final examination is usually prescribed at the end of the course. The award is commonly in the form of a certificate of study or of proficiency. A single institution confers the regular degrees. To the latter practice reference will be made hereafter.

The tuition fees are moderate, in fact lower than the average cost of text-books in the regular technical schools. The charges on the installment plan are relatively much higher. The other expenses are for a drawing outfit, paper and postage in one direction. A paid-up scholarship is non-forfeitable. Its holder may consume as much or as little time as he elects for the completion of his course. The unused portion of a scholarship is transferable at the option of the owner. In short, the financial policy in general is quite liberal to the student.

The only educational requisites are a knowledge of reading and writing. The courses in pure mathematics begin with arithmetic and end with trigonometry. The instruction papers on technical subjects are usually prepared by graduate engineers, sometimes men of considerable ability and practical experience, but not always connected with the schools. Such men also exercise a general supervision of the correspondence in their respective specialties. The ordinary routine of correcting papers and of letter-writing is entrusted to lower-salaried assistants, often young women especially trained for these duties. Such correspondence is reviewed by some one in higher authority, and, if necessary, revised before forwarding. Communications are written, as a rule, by hand, rather than by mechanical means. This practice, while entailing a considerably greater outlay, seems to appeal to a certain student-element as more distinctly personal, and serves to allay suspicion that the methods are in any way stereotyped. In the better schools, the administrative details in general are thoroughly systematized and all operations conducted with business-like regularity and dispatch.

That the net influence of these schools is for good does not seem to admit of a reasonable doubt. They are extending a helpful hand to large numbers of aspiring people who have not the remotest prospect of gaining better advantages through the regular channels. They hold out opportunities of greater promise than can be looked for from average efforts at self-instruction.

Such adverse criticisms as suggest themselves are applicable in part to certain practices of the schools, and in part to defects inherent in the correspondence system. The distincton is, however, not always easily drawn.

Since the schools are operated primarily for revenue, it is directly to their interest to appeal to the largest numbers. The curriculum is therefore designed to include the most elementary subjects. These may be omitted by students who pass the preliminary examinations. However, the statistics of one of the leading schools indicate that less than ten per-cent of the applicants can meet the requirements in arithmetic. Thus there is the necessity on the one hand of beginning with the most elementary studies and, on the other, of not wearying the student with an excessive amount of preparatory work before entering upon the technical courses proper. The compromise appears in narrow, short-cut courses. It carries with it, also, the omission of analytic geometry and the calculus.

The effect of all this on the more advanced courses is easily conjectured. The more difficult features of a subject are suppressed or treated in a superficial manner. Important formulas that cannot be passed unnoticed are sometimes presented without a hint as to their derivation or their practical limitations.

Through the courtesy of certain schools the writer has had the opportunity of examining complete files of their instruction papers. In point of general makeup, that is paper, typography, illustrating and indexing, they are superior to many modern text-books. The excellence of the illustrations is an especially praiseworthy feature. In fact, it may be said that they are of a profusion and elaborateness not always in keeping with the context. Upon closer scrutiny one's impressions are apt to be less favorable than upon the first cursory examination. However, on the whole, the texts are written with much care and discrimination. It is readily seen that the authors' task is by no means an easy one. The texts must be concise, and, at the same time, veritable models of clearness. The mathematical work must be reduced to the simplest form, inadequate though it may be, for the purpose in view. General forms of treatment must yield to the presentation of simple, special cases. As a partial offset to these deficiencies, and presumably with an eye to the demands of their peculiar constituency, there is an evident effort to give the studies as practical a trend as possible. In certain subjects a good deal of valuable information is given of a kind not ordinarily found in text-books. In point of thoroughness and general excellence, the courses, on the whole, are, however, in no wise comparable with those offered in the regular technical schools. It is, of course, only reasonable to assume that, since the field is comparatively new, the methods are as yet somewhat tentative. Nevertheless, for reasons previously suggested, there appears to be little prospect of any substantial gain in thoroughness without raising the matriculation requirements to a standard that would usually prove prohibitive. Perhaps the solution will eventually be found in graded courses. In fact some beginnings in that direction are already discernible.

In the meantime, it may be fairly charged that the schools are far too pretentious in their claims. Without attempting to particularize, the evidence in this respect is unmistakable. Engineering instruction of a truly professional standard is not carried on by any of these institutions. Be it is said, however, to the credit of the technical schools that there is but one of their number which presumes to confer the regular degrees. This school claims to have received its authority by law. Its home is in the District of Columbia. It has the arrogant assurance to proclaim that the holder of its degree "will be equipped with all the theoretical knowledge that is required for the same degree in any college in the country." The courses prescribed for the degree of C.E., are Surveying, Mapping, Railway and Structural Engineering, and so-called Higher Mathematics. What is meant by the latter term can only be vaguely inferred from the published statement that "in this course the more complicated and difficult questions of the subject are taken up"; and again, "the instruction of the regular courses prepares the student to understand these more abstruse matters." Inconsistently enough, the prescribed courses in engineering require no knowledge of mathematics beyond trigonometry. Further comment appears superfluous.

Another practice of certain schools which seems deserving of strong censure is that of furnishing complete keys to those who profess to find the work too difficult. At least one school issues these keys indiscriminately to all, and claims that "if employed judiciously they can be made to save both time and labor, without injury to the student." Beyond some words of caution against their use, in other than cases of assumed necessity, the matter is left purely to the discretion of the student. One school which supplies such aids makes the naïve claim, quoted verbatim, that "every student who has enrolled with us has successfully graduated from our schools." Let it be presumed that the term 'student' is here meant in the somewhat exclusive sense of 'one devoted to study.'

It should in fairness be observed that, as a rule, these institutions do not claim to stand on an equal plane with the regular schools. On the contrary, in some instances they go so far as to advise persons who have the time and means, to obtain a college education. This is followed, however, by the most unqualified and unmeasured assertions in proof of the superiority of the correspondence system, particular stress being laid on the claim that in these courses nothing of any real practical value is omitted, while all so-called useless matter is eliminated. The effect of this is especially harmful in so far as it serves to imbue prospective students with the notion that the day is passed for making great efforts and sacrifices with a view of gaining a thorough and well-rounded education by the older methods. This tendency of diverting students from the regular technical schools is perhaps more than neutralized by the stimulus given to technical education generally among the many who would not have been reached by other means.

In general, the schools place much dependence on the oftentimes glowing testimonials of those who have come under their instruction. Without discrediting the authenticity of such evidence, it may be properly insisted that it is entitled to little weight. It comes as the testimony of individuals just emerging from darkness into half-light. Their horizon is too narrow for accurate orientation.

In an attempt at gaging the probable influence of these schools, the criterion of numbers is no less misleading. Where thousands enroll, but few graduate. To complete the more extensive courses, elementary though they are, requires a degree of perseverance and self-denial in the utilization of spare moments that few can muster. It is to be remembered that the students, as a rule, are employed at regular vocations. Through seductive advertising literature and the personal solicitation of agents, many are persuaded to enlist without adequate conception of the sacrifices entailed. According to statistics kindly furnished by one of the leading schools, of a thousand persons who entered upon a certain course four years ago, thirty per-cent, on the average, have not yet finished arithmetic; a further forty per-cent, that is, a total of seventy per-cent, have completed no subject beyond arithmetic; and only one-half of one per-cent, or five persons have graduated.

To sum the matter up, it is believed that any attempt at giving, by the correspondence method, a broad and thorough education to persons who at the same time follow their daily occupations must end in failure. Narrow and shallow courses, of the kind described, may be regarded as the inevitable issue. It should, however, again be emphasized that in the absence of better means, and in so far as these schools are honestly conducted, they hold out opportunities to the many, and rewards to the few, well worth the effort of attainment. And, in conclusion, their highest destiny will have been achieved if by their coming they shall but quicken the birth of a system of popular education—industrial and commercial—worthy, in every sense, of this great nation.

DISCUSSION.

PROFESSOR MERRIMAN said that a grave question had been brought before the Society by this excellent paper of Professor Marburg, namely, whether the correspondence schools at this time promoted engineering education. He thought it was about twelve or fifteen years since such schools first began, and that five years ago, if this question had been asked, he should have said unhesitatingly that these schools had promoted engineering education; that they had reached a class of men which never could have been reached by the ordinary technical engineering schools, and that many of the pupils of these schools, inspired by their study, and encouraged by their success, would go on and become students in the regular engineering colleges. The speaker stated that the success of some of these early schools had been so great that they had paid dividends as high as eighteen per-cent on their capital stock, and that such commercial success had caused many other schools to go into the field with such consequences as had been fully set forth in the able paper of Professor Marburg. He expressed his belief that the question has now assumed a very different character; that at present there exist a large number of correspondence schools which employ methods of advertising and of obtaining students which are very repulsive. It seemed to him questionable whether the present method of the correspondence schools in dealing with their students is fair in every respect, and on the whole, he was of the opinion that these schools do not at the present day promote engineering education as they had done in the past.

Professor Williston remarked that he had had an opportunity to learn something about two of these correspondence schools, and that while he of course realized that many schools might be unscrupulous in their methods, yet he had been much impressed with the apparently honest and straightforward manner in which the particular schools to which he referred did business. The speaker alluded to the willingness of these schools to recommend to prospective students a more thorough course in a regular school or college wherever it was possible to obtain it, admitting the superiority of personal instruction to that which they can offer. While he believed that the best results are possible only where students can come directly in contact with able teachers and receive inspiration from them, yet where nothing else is possible, he would recommend the correspondence school, and he had, in fact, done this under the circumstances mentioned. In the speaker's opinion, the correspondence schools are filling a want, and are filling it remarkably well, considering the almost insuperable difficulties under which they work, of never even seeing the greater part of their pupils; and, in spite of the fact that some might be abusing their opportunities, he nevertheless believed that they are doing a great deal of good work.

The speaker considered one question, suggested by the paper of Professor Marburg, of particular importance, namely, the need of some adequate means of assisting those who can not avail themselves of the regular courses of instruction given in our best engineering colleges. There are doubtless a great many young men who are unable, for lack of time, or means, or previous preparation, to attend a four-year college course and who are not aspiring to fit themselves to become engineers, in the large, broad sense of that term, but who wish, nevertheless, to prepare themselves better for industrial pursuits. It seemed to him that the opportunities for securing such secondary technical education in this country are at present so few that a good field exists for the correspondence schools.

Professor Marburg said that, in the light of the remarks just offered, it might appear that some of the criticisms he had made against the advertising methods of the correspondence schools in general were unduly severe. He therefore wished to state that he had examined carefully the circulars of all correspondence schools that had come to his notice and he would repeat what had been stated in the paper, that as a rule they do not claim to offer advantages equal to those afforded by the regular colleges. Yet, while they did not venture to commit themselves explicitly to a claim so evidently untenable, their arguments in favor of the correspondence methods were all in that direction. The speaker referred to an amusing and characteristic, though somewhat extreme, instance in illustration of this point, which appeared in the circular of one of the technical correspondence schools. It was in the shape of a picture showing that in the regular college course the lecture of the professor went in at one ear of the student and passed out at the other, as indicated by a dotted line, while in the case of the correspondence school the dotted line terminated somewhere within the cranium of the individual, thus leading irresistibly to the conclusion that the benefit derived by the correspondence-school student was superior to that obtained by the other.

The speaker said that he wished to take this opportunity of suggesting to the Society the propriety of taking some action at the next business meeting, looking to the appointment of a committee in accordance with the suggestion of Past-President Johnson, to report on the general question of industrial schools, and that he hoped, if such a committee were appointed, Professor Johnson, who was then abroad studying such schools in European countries, might be tendered the chairmanship.

Professor Aldrich thought the subject of the paper a very timely and important one for discussion. He was of the opinion that the proper stand for the Society to take in this matter at the present time would be a conservative one. The speaker observed that there is a certain practical side of the question which the Society must soon decide, at least as individuals, namely, the credit that should be allowed young men coming from the correspondence schools to the technical schools, with certificates or diplomas for certain work completed in the former schools. He thought it might be well, also, if this question could be acted upon by the Society as a body, or by a Committee. Presumably some of the members had attempted already to decide this matter and know the difficulties involved. He felt satisfied that there is not a member of the Society who does not believe in the greater efficiency of the instruction of the college compared with that of the correspondence school. At the same time, he believed that there is no question but that at the present time the correspondence schools are diffusing a form of technical knowledge throughout the country which is proving quite helpful to many young men engaged in industrial work. The speaker wished to add a word with reference to night-schools. Instruction in these schools has to be given when the student is physically exhausted, and differs greatly, in kind and quality, from that imparted during the day to our own students. In the night-schools of England they are seeking to train superintendents, foremen and managers, or directors of work. To some extent that is what several of the corresponding schools are aiming to develop in this country. In Germany, on the other hand, they are prosecuting this work by the much more effective day-school methods with such excellent results that their manufactures and commercial enterprises are being pushed now into the four corners of the earth. The question presented to us now is, whether to approach this problem by the English or by the German method. In case, however, the choice has to lie between the correspondence schools and the night schools, the speaker would prefer the former.

Professor Hatt thought that we should, in judging these correspondence schools, distinguish between the business methods of the managers, and the work of the individual instructors. In his opinion, an average apprentice who works full time in the shop, is not in condition to avail himself of instruction, however accessible, and that any widespread and successful scheme of instruction for working boys should enlist the coöperation of employers, to the end that a part of the working day of student-apprentices might be devoted to study. He had had some of the graduates of these correspondence schools in his classes, and had noticed a tendency on their part to overvalue definite formulas, although they were careful in the use of units.

Professor Waldo suggested, that while the facts had been so admirably presented on the one side of this subject, there is, nevertheless, another view that ought not to be neglected. He said that he heartily agreed with what had been said of the advertising methods of the correspondence schools, but that that is not the only way in which these schools should be judged. Another way is to go into small, out-of-the-way communities, in which young men have come under the instruction of correspondence schools, and note what effect these are having upon their lives. It seemed to him that a full view of the matter can not be gained unless that is done. The speaker had in mind the case of a young man who, because of poverty and other reasons, had been denied an opportunity of receiving a higher education in engineering. This young man, while an apprentice in a machine shop, had taken advantage of a course with a correspondence school, and had been greatly helped thereby.

In the speaker's opinion, the moral influence of the correspondence schools upon the many pupils is an important element not to be overlooked. He wished, moreover, to confirm the view expressed in the paper that the work of the correspondence schools advanced in a measure the interests of higher education; and that it is not only a valuable assistance to a class of men that can not be reached in any other way, but that, finally, many of them are brought into the regular technical schools.

Professor Allen thought it might be taken for granted as true that the correspondence schools have accomplished, in certain respects, a great deal of good, and, as equally true, that they are likely oftentimes to mislead the public. However, even if these schools do to a greater or less extent deceive the public, it is not the function of this Society to attempt to regulate such matters. It seemed to him that the Society was greatly indebted to Professor Marburg for the excellent presentation of facts concerning which many of the members had probably not been especially well informed.

PROFESSOR MAGRUDER was of the opinion that some of the correspondence schools do a great deal of good while others do a great deal of harm. The natural tendency of schools which fail to help their students is to quickly go to the wall, as some quack schools had already done. It had come to his notice that the manager of one of the largest manufacturing establishments in this state was a graduate of one of the correspondence schools, and that he was highly in favor of these schools. It seems that he had been unable to get a technical education in a college and had therefore resorted to the correspondence system for his education; and that he had since remained thoroughly in sympathy with the same. The last time the speaker had seen this man, he had pointed out his correspondence-school library, saying that he frequently found it advantageous to refer to those books in connection with his daily work, and that he was advising his subordinates to take a like advantage of the correspondence-school system. The speaker referred to other instances that had come under his observation, of students who had attempted to gain an education in this way and had become completely disgusted with the charlatanism practiced by some of these alleged schools; in short, that everything depends on the character of the particular school patronized. One of the assistant professors of the Ohio State University who had been a writer for one of the correspondence schools and who approved heartily of their methods, where properly developed, had told him that if he wanted to study exactness and clearness of expression, he should try to get a position requiring him to write for people who had had nothing beyond a common school education and that he could only in this way appreciate the difficulty. The speaker declared that in the Ohio State University they had met the same problem that professor Aldrich had spoken of, namely, what should be done with graduates or students of correspondence schools when they came to the regular schools. He said he considered that a very important subject, and that in his experience these young men had come with the idea that they were full-fledged engineers, whereas they had simply dabbled in this, that or the other, and that the first duty of the professor in the regular school is to undeceive them.

A VISITOR arose to remark that, inasmuch as he was not a member of the Society, he felt some hesitation in joining in the discussion of a subject in which he felt greatly interested, since he himself had been a student in one of the correspondence schools. He had entered an engineer's office some twelve years since without a technical education, and had attempted to make up his deficiency by self-study. He had succeeded very well in algebra, but could not progress further without the aid of a teacher. At the end of four or five years, he found that he had accomplished very little and his attention was then attracted to one of the correspondence schools. The speaker stated that his studies for a period of three years, under the direction of this school, had been a great aid to him; that instead of being employed now on construction work with an engineer over him, he is himself in charge of other men. While he was satisfied that he would have derived more benefit from a regular technical course, yet he knew that the course he had taken had been of great advantage.

PRESIDENT MENDENHALL hoped the Society would indulge him in a single remark in this discussion, and that, as bearing upon a fact which he thought had perhaps not yet been emphasized, namely, the decrease, almost to zero at the present time, of the difficulties in the way of any one obtaining a thorough course of training in engineering. He said that the result of his observations during the past ten years was that these difficulties had been constantly decreasing, and in a wonderfully rapid ratio. He doubted that any young man who has the spirit and the courage and the pluck would find any difficulty that he can not overcome in the way of obtaining a thorough training in an engineering school. The speaker observed that there are many institutions in this country which have excellent engineering departments in which no tuition is charged. These opportunities have arisen within the last ten years. Again, there are a large number of scholarships and fellowships that are given in various institutions without cost. The speaker had investigated this question to some extent, and had been particularly impressed with the fact that there remains little difficulty in the way of obtaining a thorough training in an engineering school to any one who so desires. He had, indeed, come to the conclusion that it has become almost too easy for a man to gain an education in engineering. Very often students are aided in various ways, on account of their disposition and desires, who are really not fit to become engineers, and never will become such. He thought that in considering this question the Society might well leave out of account the difficulties that prevent deserving young men from gaining admission to the best engineering schools.

ADVANCED ALGEBRA IN ENGINEERING AND OTHER COLLEGE COURSES.

BY FREDERICK L. EMORY,

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It is very generally acknowledged that mathematics is the backbone of engineering courses in universities and professional schools. Such being the case, it would seem logical that each part or vertebra should be designed for its special demands, and follow one upon another in such a manner as to produce a symmetrical and strong structure. That such a structure exists in most courses is believed to be true, but there seems to be, in some cases at least, one point that might be improved. The relative place of the subject of advanced algebra in universities, where both general-arts students and technical students enter and continue in the same courses and classes, is the one to which reference is made.

The general-arts student studies the subject as a culture study, while the technical student pursues it as a training for future application in the practical and theoretical treatment of applied mechanics and mathematics. If it were left out of the course for the arts student, he could substitute the elements of trigonometry or geometry without much detriment, and since his work in mathematics usually stops with trigonometry or analytic geometry, he could scarcely be considered as having lost a great deal, inasmuch as a deep knowledge of algebra is not essential in order to take up with success the elementary treatises on geometry or trigonometry or analytics usually employed.

The same would apply to the technical student, except that the necessity of his having this branch covered before entering upon the applications to mechanics might be met by giving to such a student the usual advanced-algebra course along with the calculus, or supplementing the calculus and in connection with differential equations.

The question intended to be brought out in this discussion is: Would it not be better for the engineering student to have the courses in advanced algebra succeed those in calculus rather than to precede the solid geometry and trigonometry; and would not the general-arts student be rather benefited by such a transposition? It seems to me it would be an advantage to both. It appears a very poor pedagogical principle to teach rules of thumb, for that is what is done in every course in which it is attempted to teach under advanced algebra those principles which are so clearly and easily deduced by the calculus as mathematical philosophy. Would it not be better to postpone the subject until the student has acquired a mathematical reasoning, rather than to cram his brain with rules of thumb the correctness or falsity of which he cannot see and does not believe?

There would also be a very practical gain by such postponement. My experience is, that by the time the student, who has studied advanced algebra in its present place, has followed this by solid geometry, trigonometry, analytic geometry and calculus, he has quite forgotten the rules-of-thumb learned under advanced algebra (but not the principles, for he never has learned these, they having been too advanced for him). When he comes to study the theoretical and applied mechanics, he must practically review the whole subject of higher algebra. I have found it necessary to supplement the courses just mentioned by a course in advanced algebra, theory of equations and differential equations before starting the subjects of mechanics. The question naturally arises, had not this subject better be eliminated from the earlier work and the time be spent in advancing the other elementary courses; or, what would be still better, let the time spent in imparting a memory-knowledge of advanced algebra, be devoted to additional drill in the use of factors and the rapid solution of simple equations up to and including the special cubics.

The present sequence does not produce algebraists sufficiently well trained in handling ordinary equations, not to mention the more difficult ones. It is believed that after having studied the higher branches, a better knowledge of advanced algebra may be obtained, and in less time, than with the study in its present place.

DISCUSSION.

PROFESSOR MERRIMAN thought that there were two points in this paper to which particular attention should be called. First, that the higher algebra now usually imposed upon the student at the beginning of his college course is of such a character that it might well be deferred until a later period. In this the speaker concurred entirely. The second point, and one to which the speaker wished to take exception, was found in the author's statement as to the necessity of supplementing the course in advanced algebra by the theory of equations and differential equations before starting on the subject of mechanics. The speaker believed that if, on the contrary, more time were expended on the fundamental principles of mechanics, without attempting to cover too much ground in the first instance, it would be to the greater advantage of the student. He thought we could all learn a great deal from the admirable instruction papers in mechanics issued by some of the correspondence schools in which the fundamental principles of mechanics were set forth simply, clearly and correctly without any mathematics except arithmetic. It seemed to him that the fundamental laws of mechanics and physics are entirely independent of mathematics, and need, therefore, no mathematical education for their understanding. In the speaker's judgment, the student upon entrance to the engineering college, needs a good understanding of the fundamental principles of mechanics.

Professor Hatt said that in his experience students came to the study of mechanics with sufficient facility in integration and the manipulation of equations, but that they were deficient in the underlying conceptions. He favored the proposal to introduce calculus earlier in the course and would suggest the value of graphical explanation and of numerical examples, as, for instance, working out the successive differences from the tabulation of a function in connection with the algebraic work of calculus.

Professor Bohannan observed that, within his experience as a teacher, the high schools do not give the student any proper conception of algebra as regards the fundamental laws to which its quantities and operations are subject, nor of geometry, as concerns the hypotheses which lie at its foundations; that consequently to the college freshman comes the first opportunity, in the study of so-called college algebra, to learn these things and thus to get a proper idea of the division of the domain of mathematics into the various classes. In the opinion of the speaker, if the topics of college algebra were postponed until the student has had analytical geometry and calculus, the need of taking them was not apparent, since the student will already have been often in a position where a knowledge of those topics was essential to his progress.

Professor Mees said that many of the fundamental conceptions of the calculus are constantly made use of in elementary dynamics, and students find but little difficulty in grasping these ideas. In the Rose Polytechnic Institute calculus is taken up during the third term of the Freshmen year before analytical geometry. It is then dropped for two terms of the Sophomore year and again taken up during the third term of that year and continued during the whole of the Junior year; mainly in its application to dynamical and physical problems. So far, the speaker said, the results had been satisfactory. When the subject was taken up for the second time after the interval of rest—and in the study of analytical geometry, constant reference having in the meantime been had to the calculus work of the Freshman year—it seemed to have soaked into the student and become something of a reality and not merely a mathematical artifice, such as it is too frequently looked upon by the student.

Professor McNair remarked that he had noticed what seemed to be a tendency on the part of some speakers in this discussion to draw a sharp line of distinction between calculus, higher algebra, trigonometry, and so on, for the various other branches of mathematics. He thought that the professors of both mathematics and engineering ought not to lose sight of the fact that these divisions are, after all, largely arbitrary.

DIRECT CURRENT LABORATORY WORK IN AN ELECTRICAL ENGINEERING COURSE.

BY FRANK W. SPRINGER,

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The technical or engineering college is of recent origin. Less than twenty-five years ago only the most general courses were given in the sciences. Engineers of that period, if they had a college education at all, were schooled in the classics, philosophy and mathematics. They were thus compelled to get their engineering education from practice, and their success as engineers depended largely on self-education and genius. It took many years of practice in which to gather the technical knowledge necessary to success, and, consequently, engineers were not only well beyond middle-age before attaining prominence, but, having very little theoretical knowledge, they were not fitted to meet rapid changes even in their own lines.

Coincident with, and largely on account of, the industrial application of electricity, there arose a great demand for engineers who were adapted by education to keep up with the rapid progress that was being made in all branches of engineering. The practical men, as a class, could only do as they had done before; they did not know, nor could they readily understand the new theories. The theoretical men, on the other hand, were of little assistance to them, because their knowledge, being of a general nature, was not in a condition to be applied. Thus there came a clash between theory and practice. Craftsmen laughed at the new-fangled theories which would not work in practice, and the theorists were handicapped because mechanics could not make special application of general principles. It is evident that the above conditions demanded a combination of the qualities of the theorist or physicist and mechanic, *i. e.*, technically educated engineers.

Because of the above demands, the technical college was developed from the scientific, just as the scientific had already branched off from the classical. Then there arose the question as to just how much practical work should be given the student. Four years had long since become the regulation length of a college course, and if there was any tendency to change it was to shorten rather than to lengthen the time. It had already been necessary to strike out many of the so-called culture studies from the curriculum to make room for the technical. The latter having been introduced, it was necessary, in order to teach practice, either to reduce the time devoted to theoretical instruction, or to cut out more of the culture studies, such as languages, history, etc. Some colleges went so far as to offer courses in which nothing was taught but shop-work and strictly engineering subjects. This simply amounted to a quick way of learning a trade. Such courses, however, have been dropped in most cases, because it was found that graduates either pursued the trade thus learned, which they could perhaps better have acquired as apprentices, or else they took enough more work to complete the regular four-year course.

The question of the relative amounts of time to be assigned to laboratory or shop-work and class-room studies was, and still is, unsettled, and practice varies greatly in the different engineering colleges.

The Electrical Department of the University of Minnesota does not aim to teach trades, but rather to turn out men who are well grounded in theory. Practice, which is but the continued application of the same principles, can be best obtained outside of college. Theory cannot be taught anywhere else to better advantage than in school. (It may be remarked parenthetically, that all engineering students are advised to use their summer vacations to the best possible advantage in securing experience along their special lines. Students who are backward in the application of theories are sometimes advised to stay out of school a year for the same purpose.) Sufficient laboratory work is given, therefore, to clinch the theory, working on the idea that, from an engineer's stand-point, what one does not know how to apply he does not know at all.

When just enough laboratory work is given to enable the average student to master the maximum amount of theory, the term 'theoretical man,' no longer means one who knows a great deal, but can apply little ; but rather one who knows the fundamental principles and can apply them, and who knows that he can. Practice will, of course, make him more proficient. To illustrate—we have no hesitation in recommending many of our electrical students to take charge of electric power-houses and the like immediately on graduation. Many of them have done it with success and others have taken positions of responsibility in other branches of electrical engineering.

When it is learned that students are thus fitted with an aggregate of only 300 hours of electrical laboratory instruction, most practical men may hesitate to credit the graduate with much knowledge and will probably be interested to know something in detail of the laboratory methods used.

To start with, it will not be contended that the student has learned most of what he knows in the laboratory; on the contrary, notwithstanding the fact that shops and laboratories are indispensable to an engineering college, the greater part of the technical training is acquired in the class and lecture room.

During the first two years the work is much the same as in the regular scientific course, with the exception of the required shop work and drawing. The student acquires a good general education, learns many fundamental principles, most of which he applies in some prescribed way, such as problems and outlined laboratory experiments. He is especially well grounded in physics and mathematics. The subject of mechanics is studied during all three terms of the third year. Physics is continued in lecture, class and laboratory, the first two terms of the same year. In the second term of the third year, there is a course of lectures on industrial electricity, treating of its application, the use and abuse of instruments, and generally outlining the technical work to follow. In the third term of the third year the subject of dynamo-electric machinery is taken up up four times a week in the class room, using S. P. Thompson's text-book, which is supplemented by lectures and by reference to other books on the same subject. This is accompanied by a corresponding course of ten hours a week in the electrical laboratory, which is the first work that is similar in any way to commercial electrical engineering.

As the methods used in this course depend somewhat on the preparation received in the previous two terms in the physical laboratory, it will be well to outline the latter.

Out of a total of 46 experiments, requiring in the aggregate 80 hours in the laboratory, the following are selected to indicate the nature of the course:

Determination of "H" by two methods. Tangent galvanometer. Calibration of ammeter and potential galvanometer. Determination of absolute resistance and electromotive force, calorimeter method. Resistance and potential problems. Work. Efficiency. Magnetic properties of iron; B., "mu.," etc. Ballistic galvanometer. Determination of capacity of condenser. Coefficients of induction.

On finishing the above, the student has acquired a thorough understanding of the theory of electric measurements, an acquaintance with the construction, adjustment and care of delicate electrical instruments, has learned how to take observations, keep notes, and to calculate limits of error. While correct manipulation is necessary to produce accurate results, which are insisted upon, a thorough understanding of the fundamental principles is held paramount.

Thus, after a preparation extending over a period of nearly three years, the student has yet to acquire that special knowledge and training which will entitle him to the degree of Electrical Engineer.

As has already been stated, his practical electrical experience begins with 120 hours (M. E. students take 72) in the third term of the third year, and is briefly as follows:

(1) About two weeks, or 20 hours, are spent in getting acquainted with the electrical laboratory by tracing and making diagrammatic sketches of the circuits of the switch-boards, room-wiring, storage-battery plant, and machines. Different methods, as found necessary, are used in locating the circuits, such as: by sight, pulling the wires, magneto, incandescent lamp, voltmeter, and compass, while concealed wires are found by the use of the telephone and exploring coil.

(2) Soldering, splicing wire, and wiring.

(3) General care of dynamo electric machinery, setting brushes, sand-papering commutators, oils and filters, and trimming arc lamps.

(4) Experimenting with the electric arc, using a magnet, compass, and lens.

(5) Construction of an ammeter and voltmeter from a galvanometer.

(6) Calibration of an ammeter and voltmeter.

7) Test of fuse wires.

(8) Insulation testing (*a*) with high resistance voltmeter, (*b*) with bridge.

(9) Study of a dynamo or motor.

(A) Measurement of the resistence of the armature and field coils: (*a*) by use of ammeter and voltmeter, (*b*) by use of bridge.

(B) Circular mils per ampère in coils, etc.

(C) Sketch of the magnetic circuit.

(D) Determination of the magnetic leakage coefficient for different field excitations by the ballistic galvanometer and temporary-coil method.

(E) (*a*) Operation as a dynamo and as a motor, regulation, effect of shifting the brushes, etc. (*b*) Running as a motor with the field excited by the armature only.

(10) Potential curves around the commutator, showing the distribution of the magnetic field.

(11) Application of the fundamental equation $E = \frac{NZn}{10^8}$ to a dynamo and to a motor, to find "N" and "Z" where only the outside layer of the armature winding can be counted.

(12) Magnetization curves of a dynamo or motor.

(13) Determination of the series turns and size of wire necessary to compound a shunt dynamo for a certain per-cent. rise in voltage at maximum load.

(14) Application of the fundamental equation $f = \frac{Hc1}{10}$. Given the machine used in exp. (9), to compute the *torque* under certain conditions and to prove by experiment.

(15) Application of the fundamental equation of the magnetic circuit

$$N = \frac{\frac{4\pi Sc}{10}}{\Sigma \frac{1}{A_{\mu}}}$$

Given a machine to

find the ampère-turns for different parts of the magnetic circuit.

(16) Primary and secondary cells, care of, charging and discharging, measurement of the internal resistance, and time tests with curves showing current, voltage, etc.

(17) The principal characteristic curves of, (*a*) shunt dynamo, (*b*) series dynamo and (*c*) compound dynamo.

(18) Characteristic curves of arc dynamos; constant-current and constant-potential arc lamps.

(19) Three-wire distribution experiment.

(20) Primary calibration of ammeters and voltmeters, using the potentiometer and standard resistances and cells. Watt-meter calibration.

(21) Electrical and commercial efficiency curves of a dynamo or motor, separation of all losses, use of the Prony brake and cradle dynamometer, and determination of the best speed.

(22) Temperature, time, resistance and current test of coils.

(23) Static and gyrostatic balance of armatures.

(24) Station operating.

Laboratory Methods.

The theory is given first in class. To illustrate, take experiment (11): The equation $E = \frac{NZn}{10^8}$ and its application to dynamos and motors are discussed and explained in the class-room. A problem is then given in which "N" is the unknown quantity. As soon as possible after this, generally not more than a week, the experiment is taken up in the laboratory.

There is in almost every experiment a definite numerical result to be obtained. As accurate results are insisted upon, and instruments used are checked in some way before and after the experiment, the student soon learns that success depends entirely on his own persistent and careful efforts. Having once learned this his work begins to count, he will accomplish more alone than otherwise, and with an instructor at his elbow. If he cannot learn to feel his own strength, he will never start an experiment with any other idea than that he may perhaps get a result, which would be ruinous to all prospects of success. Such a student would soon be spending half his time finding excuses for what he had done the other half.

An instrument which does not agree with itself within a small known limit of error is unfit for use by students. Nothing will more effectively prevent fudging and guessing, and will instill a regard for at least the technical truth, than the use of accurate instruments and the demands for accurate results. Poor instruments, poor methods, and an instructor who anticipates every new idea and danger, will spoil the best of students.

With good instruments and good methods, most students will do better in the long run if allowed to use their own judgment as to when they need assistance. And, in fact, if allowed to think for themselves at the beginning, they soon learn to enjoy using their own judgment, and will not seek help until actually cornered, and even then sometimes obtain the desired information from a fellow-student. This is well, because where the advice of an instructor would be accepted without question, that of a fellow-student is carefully considered before being utilized.

Some students have difficulty in losing the primary school idea that their every move is watched and that if about to make a false step, they will be warned in some providential manner in time to save themselves and instruments. In work where not only instruments but even life itself must be entrusted to the memory, such helplessness is absolutely dangerous, for there is often nothing about a conductor to indicate whether it is charged or not, and pressure as high as 40,000 volts is used for experimental purposes in the electrical laboratory of the University of Minnesota. It must not be thought, however, that such dangerous pressures are permitted to be used by beginners. On the contrary, the above statement is made to show the necessity of a student developing, as soon as possible, a capacity for independent action, an appreciation of responsibility, good judgment and correct habits. He gets the first by acting independently, the second by being responsible; good judgment comes only from using judgment, and correct habits from the repeated use of proper methods.

It is sometimes necessary to frankly tell students that they are not watched, and leave them alone with the understanding that results will tell the whole story. This method sometimes costs the department the repair of an instrument in the early part of a student's career, but is, no doubt, a saving in the end, because once a student has learned that it is his own head, and not some unseen hand that keeps him out of trouble, he seldom has any difficulty.

The prescribed list of experiments is followed only so far as one naturally leads up to another. Experiments are selected to fit the needs of different students, who are encouraged to devise new ones for themselves. Shop and tools, as well as the regular laboratory instruments, are placed at their disposal at all times. The laboratory is regularly open afternoons between two and six, yet experimenters can be found there at any time between half-past seven in the morning and two at night. It is endeavored as far as possible, to have the ten hours a week put in, in consecutive four-hour periods, as it is found that the less the time is broken up, the more work can be done.

Every student keeps in a note-book, a complete account of all experiments undertaken, which book is turned in at the end of the term; and, together with the time and general character of the work done in the laboratory, furnishes the basis of marking and grading.

It might be supposed, where full lee-way is given, and no restriction placed on the amount of work done, within reasonable limits, that the students would soon be of all sorts of grades. This is the case, of course, to an extent but really is not objectionable, because extra work done is the individual's own gain.

A condition which tends to increase the amount accomplished by the poorer students, is that the best men do not object at all, as a rule, to having the poorest men as laboratory partners. While in one way this is not a good arrangement for the weak student, since his partner does most of the headwork, yet, inasmuch as it keeps him up with the class, and gives him an opportunity to clinch the theory as soon as it is learned, it is probably the best that can be done, since the required number of experiments cannot be limited to what the poorest man can do working alone. Another way of making the grade uniform, and one which is usually agreeable to the students, is for those who have had practical experience to select as partners those who have not had the same opportunities.

Experiment No. 24—Station Operating—is usually done outside of regular laboratory time and consists in running the dynamos to furnish extra lights for University evening affairs. For this the students are sometimes paid, which is also the case with wiring, those who can do such work being given the preference over outside help.

To close now with a brief accounting of the remaining 180 hours: Seventy hours are given respectively to the first and second terms of the Senior year. The first term's work is on alternating currents and that of the second on alternating currents and photometry, arc lights and incandescent lights. The remaining 40 hours are taken up by plant operation in the second term of the Senior year, operating the university lighting plant under the direction of the regular engineer.

The same general plan is followed throughout, the theory being first taken up in the class or lecture room and then followed immediately by an experimental demonstration in the laboratory.

A HYDROCARBON ENGINE LABORATORY EQUIPMENT.

BY PROFESSOR WM. T. MAGRUDER,

Professor of Mechanical Engineering, Ohio State University, Columbus, Ohio.

The mechanical engineering laboratory of the Ohio State University has been fitted up for the testing of gas, gasoline and oil engines, as undergraduate student exercises, for original thesis work and for advanced or post-graduate exercises and research work. Originally it possessed only an Otto slide-valve type of gas engine, inherited from the department of physics. In January, 1898, it secured the use of a nominal ten actual horse-power, non-scavenging, Otto cycle, gas and gasoline engine, fitted up with both hot-tube and electric ignition, fly-ball, hit-and-miss governor, and with means provided for changing the clearance; and also of a nominal six actual horse-power, scavenging, Otto cycle, gas engine with hot tube ignition and with inertia hit-and-miss governor. The latter has recently been replaced by a gas and gasoline engine, nominally of six actual horse-power, provided with a hit-and-miss, inertia governor and with means for changing the clearance. Later, we expect to install an oil engine.

In the measurement of the liquid fuel, oil sufficient for a run is put in a galvanized iron can, out of doors, which is provided with a float and a calibrated scale reading by fractions of gallons and by liters. From this can, the engine pumps its supply, and to it the excess flows.

In the measurement of the gaseous fuel, it was considered, and has been found, to be desirable to be able to control the pressure of the gas and also to get gas of a uniform quality during a test. To attain these ends a closed gas-holder, four feet diameter and eighteen feet long horizontally, and containing two hundred and twenty-five cubic feet was, for want of a better place, hung from the ceiling and supported on the wall. Pipes were so arranged that water entered it at the bottom, direct from the city mains, at a pressure which was regulated by a two-inch valve or by a three-fourth-inch by-pass valve. The gas-holder is emptied of water by opening a valve which connects with the sewer in the prolongation of the inlet pipe. The gas is taken into and taken out of the holder at the top, a check-valve being provided to prevent the water following the gas after the holder has become completely filled. The gas from the main or from the holder is then led either directly, or through a thirty-light tin meter, to the engines. If through the meter, the reading of the meter is a check on the reading of the gas-holder, and also a test of the meter at that pressure and temperature. To the end of the holder is attached a four-foot water-gage glass, provided with self-closing cocks in case of the breakage of the glass. The holder was calibrated by filling it with water which had been carefully measured in the standard cubic-foot measure of the department of physics, and graduations made on the scale attached to the water-gage glass. It is thought that the error of reading the gas consumption by this method need not be greater than one-tenth cubic foot. The gas pressure is measured by manometers, and is kept constant by an observer who regulates correspondingly the two-inch and the three-fourth-inch water inlet valves above referred to. The limit of gas pressure obtainable at present is the strength of the gas-bags; but, with these disconnected, it is thought that a pressure of twenty pounds can be obtained, due to a pressure of forty pounds in the city mains. It will thus be seen that the quantity of gas consumed in a test is obtained by measuring the quantity of water required to displace that many cubic feet of gas. The calorific value of the gas is obtained by a Mahler calorimeter by the department of metallurgy, and by a Junker calorimeter connected to the gas pipe leading from the gas-holder to the engine. The gas is led to the engine by a one and one-half-inch pipe, and through a large gas-bag, or through a floating gasometer, with the idea of giving the engine plenty of gas whenever it has need of it. The gas for the hot-tube is measured separately by a five-light tin meter.

The air is measured as usual; in our case, it is measured by a No. 4 Tobey meter of 1,500 cubic feet capacity, or by two 100-light tin meters supplied by a blower, from which the air is conducted to the engine by a 6-inch galvanized iron pipe reinforced by collapse rings. The suction, or pressure, of the air is measured by a water manometer connected to the air pipe by way of a 2-gallon bottle to prevent the violent fluctuations of level due to the engine taking air. The possible variation is from 22 inches of water pressure to 22 inches of suction. The moisture of the air is measured by a Mason hygrometer.

The number of revolutions per minute, the number of admissions of gas, and the number of explosions of the gas so admitted per minute, are counted by electric contacts being made and recorded by three electric counters mounted on a portable board, each having its own switch, and also one switch in common, at the counters, at the gas-holder, and at the oil reservoir out of doors. By this means, the person who at a given time observes the reading of the gas or gasoline holder, and who, at the same instant, throws in the single switch, starts all three counters into operation at that time, and so begins the test. The other observer, at the word to start need only read the air-meter and weigh the jacket-water. The same is true of the stopping of the test.

The jacket-water may be taken either from a can 28 inches in diameter and 7 feet high, placed on platform scales on a frame so as to get the requisite head, and be delivered to the sewer; or it may be taken from the city mains, passed through the jacket and be delivered to the above-mentioned weighing can. It is so arranged that the jacket-water on its way from the weighing can to the sewer may, after leaving the jacket, go either directly there or be sprayed into the exhaust pipe, and be either trapped out of the exhaust pot or go entirely out with the exhaust gases. The temperatures of the exhaust gases are measured both at the exhaust outlet and at the exhaust pot, by mercurial thermometers having nitrogen atmospheres.

A rope-brake working on a water-cooled brake pulley, provided with internal flanges, has given entire satisfaction. We have had no trouble with, nor reason to doubt the sufficient accuracy of the Crosby gas engine indicator used.

So far about one hundred and twenty-five tests have been made under a great variety of conditions, too numerous to mention and out of place here.

A COMPARATIVE STUDY OF THE ELECTRICAL ENGINEERING COURSES GIVEN AT DIFFERENT INSTITUTIONS.

BY FRANCIS C. CALDWELL,
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Columbus, Ohio.

In the accompanying table the credit hours have been reduced, as far as possible, to a common basis. As the methods of crediting studies vary greatly in the different institutions, and as the catalogues are often indefinite in their statements, only approximate results can be hoped for, and only such have been attempted. Thus, variations in the length of the college years have been neglected, and also the length of the term has been assumed to be one-third, and the semester one-half a year. The units of credit adopted is the term-hour, namely, one hour per week for one-third of a year and thus equal to two-thirds of a semester-hour. Further, as the amount of credit allowed for laboratory, shop and drawing varies greatly, the uniform practice has been followed of calling two hours of these subjects equal to one credit hour. At a few institutions, especially Worcester and Wisconsin, some lecture work is not given the same credit as recitations, and while this is a very rational system, it seemed better, for the purpose of comparison, to give the same credit in these as in other cases. The outlines as here given have been submitted to the heads of the various departments represented, with the request that they correct any errors that they may discover; but while answers have been received from nearly all, complete revision has been undertaken only in the cases starred. Although it cannot be hoped that on errors have been overlooked, considerable care has been taken in checking the data, and it is believed that they represent the courses given at least as accurately as the average catalogue.

Among the interesting points brought out, is the striking variation in the time given to some subjects as contrasted with the comparative uniformity in others. Among the most variable ones are language, shop work, certain mechanical subjects and the non-engineering subjects; while the most uniform groups are mathematics and physics. It is interesting to note the relatively large number of courses in which economics and law are included. Shop-work is omitted entirely at Lehigh, a series of inspection visits to various shops being substituted instead. Worcester and Cornell are far above the average in shop work, while Massachusetts Institute and Columbia are as far below. The number of cases in which hydraulics in some form is given, and the small amount of time usually assigned to steam engineering are noticeable points. Inspection trips are mentioned as part of the regular work in ten courses.

Summer work is required at Columbia in drawing and designing, at Lehigh in inspection of shops, and at Worcester in shop work—this latter fact accounting for the large amount of shop-work at that institution. The course at Columbia is interesting in the extent to which it is subdivided; in one semester no less than

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ten subjects being carried at one time. At Leland Stanford such extensive use is made of the elective system that comparison was in this case impossible. It is an interesting fact that, of the eighteen institutions examined, twelve are working on the semester system.

In most cases the first year of the electrical and mechanical engineering courses is the same, and the same, or nearly so, as for the civil and mining engineering courses. In only a very few instances, however, does this year serve as a general introductory year, taken in common by all students in the technical courses. In several cases the second year is the same in electrical as in mechanical engineering, and in two or three the third is the same or nearly so.

In conclusion, it is very evident from the data collected that opinion as to what is necessary for the education of an electrical engineer varies widely at different schools. Since all of these schools turn out successful engineers, are we not forced to the conclusion, after making all allowances for differences resulting from varying conditions, that within a considerable range it does not make much difference what studies are chosen? If this is true, would it not be profitable in further modifications of the engineering courses to look toward greater uniformity, both among the different courses at the same institution, and among different institutions; and, again, could not a much more extensive system of electives be introduced, without detriment to the quality of the education furnished, and with more or less advantage to the interest taken by the student in his work?

ELECTIVE STUDIES IN ENGINEERING COURSES.

BY CLEMENT R. JONES,

Assistant Professor of Mechanical Engineering, West Virginia University,
Morgantown, W. Va.

The courses of instruction in engineering in all educational institutions are rightly affected by such local conditions as available appropriations, buildings, laboratory equipments, teaching forces and the wants and needs of the supporting districts. On the other hand, many courses of instruction are affected in a less justifiable way by college traditions, by the opinions, prejudices and even hobbies of the head professors, and, in many instances, by restrictions placed upon departments by general faculties. It thus happens that there are very few, if any, ideal courses of instruction, and almost as few that are wholly satisfactory to the professors in charge.

It is not within the power of the Society to harmonize all the different opinions of its members, nor to establish at the different institutions of learning represented uniform courses of instruction, even if such were desirable. The Society has accomplished and is accomplishing much, however, by the interchange of ideas as to what should be taught and the best methods of teaching the same. Probably even greater good has come to the Society by its very existence and thorough organization in moulding the opinion of general faculties, boards of control, and the public generally as to the importance of engineering education. It is my belief that the opinions of the Society will be consulted more and more before radical changes of courses and methods of instruction are forced upon engineering faculties. This statement will certainly be true as to the extension, to the engineering departments, of the elective system, now being adopted by a number of institutions in academic courses.

To make the position of the writer clear, it may be stated that at the West Virginia University the requirements for graduation in all departments, except law and engineering, have been made entirely elective. There the degree of "Bachelor of Arts" is given upon the completion of forty-two full courses, which must include nine courses in a major subject and six courses in a minor subject, both elected by the student. A course consists of five recitations, or lectures, per week during a term of twelve weeks, or their equivalent in laboratory or other practical work. Some members of the faculty desire to extend this system so as to include the engineering courses. They would grant the degree of A. B. to any one who completes nine courses in some engineering subject and complies with the remaining requirements mentioned. Also, any engineering subject may be elected by a general-course student having the requisite preparation.

The above statement is offered as a reason for soliciting discussion on a topic which has already been considered at least twice by the Society. However, such a case as exists at the West Virginia University has never been presented to the Society. The members who took part in the previous discussions relative to this subject will doubtless have new ideas to present, and, at the same time, the Society will be benefited by the opinions of the members who have not yet expressed themselves.

It is not the purpose of the writer to propose at this time a system of electives. His purpose is rather to get information which will throw some light upon the proper course of action for him to pursue with reference to his own institution. At the same time he hopes that the discussion will be fruitful in contributing something to the general knowledge upon the subject.

In order to open the discussion, the following brief outline, including a few of the advantages and disadvantages, is presented:

I. The first question to be considered is the advisability of adopting any system of elective requirements for engineering degrees.

The friends of the system will doubtless claim:

1. That its adoption would simplify many of the difficulties in engineering instruction by affording combinations of studies which would suit particular aptitudes and needs of the students.

2. That it would permit the student to specialize in the line of work which he intends to follow after graduation.

3. That the proper sequence of studies would give the necessary breadth to the course elected by the student.

4. That an elective system would result in better instruction, since the quality of the instruction given by a professor would be his only method of attracting students.

5. That the work required for a given amount of credit would be made more uniform.

On the other hand, it is obvious that if the system is carried out to any considerable extent, the results would be:

1. The number of classes would be greatly increased, while the average number in a class would be decreased accordingly.

2. Larger faculties, more buildings with special laboratories and increased facilities for instruction would be necessary to give opportunity for specialization.

3. The student would cut the more difficult courses, and in so doing would often omit the elements most essential to his after-success. Subjects which are considered fundamental would have to be required directly or indirectly, or they would have to be made so attractive that all students would elect them.

4. A student seldom knows the exact line of work that he is going to follow after graduation, and if left to himself would often allow his field of usefulness to be narrowed by elective courses that coincide in part, and by premature specialization.

The objections mentioned, though very grave, do not prove that elective studies have no place in engineering courses. They indicate rather that the system has its limitations, and that some restriction must be placed upon it both for financial and pedagogical reasons. What these restrictions should be, is open to question.

II. The next matter then to be considered is the form the elective system may take, and a comparison of this system with that of prescribed courses.

1. The course system. In this system a student is usually obliged to elect his entire four-year work at the beginning of the Freshman year.

2. The course system with stated alternatives or options. The optional studies are usually in the Senior year only, and, therefore, the choice between the options does not have to be made until late in the course. This is a very good method when the teaching corps is large enough to offer more subjects than in the regular prescribed course. This system admits of some specialization and renders administration easier than the elective system. If carried to any extent, it would require a large faculty of specialists and very extensive and costly equipment.

3. The combined course and elective system. In this the work is partly prescribed and partly elective. The distribution of the work may be made according to the outline given below, any term of which may be eliminated:

A. Required general culture studies, plus elective general culture studies.

B. Required semi-technical studies, plus elective semi-technical studies.

C. Required professional studies, plus elective professional studies.

Or, required studies plus elective studies in which electives may be free, or partly restricted.

There is a tendency now to raise preparatory requirements so as to eliminate, as far as possible, general culture subjects from the college curriculum. Semi-technical studies are also being reduced to a minimum, so that there is not a very great opportunity for allowing electives in either group *A* or *B*. It would seem then that elective studies should be limited to professional subjects or be made free.

It is evident that in small colleges where there are only a few electives to choose from, there is practically no difference between this system and the course system with options.

4. The elective system. This might take several forms.

(1) Where the student elects his major subject and the minor studies are fixed by the major professor or by a committee.

(2) Where the student elects both his major and minor studies by groups.

(3) Where the student, observing the proper sequence of studies, selects the required number of courses for graduation from those offered by the engineering college.

The system designated (2) corresponds closely with the one proposed for adoption in the engineering departments of West Virginia University. If this were adopted, only nine related professional courses would be required. The six minor courses would not necessarily be in engineering, while the only restriction placed upon the remaining twenty-seven courses would be the observance of the proper sequence of studies.

III. The degree to be given with an elective system of requirements.

The degrees heretofore given for undergraduate work had varied widely. The writer has always preferred that the technical degree should be distinct from the academic, and that it should also indicate to some extent the character of the studies pursued. With a system where much freedom of election prevails, it would be almost impossible for the degree to designate the specialty of the one receiving it. In such cases there would seem to be good reason for adopting a more general degree, as "Bachelor of Science." I believe that a degree like "Bachelor of Arts" would not be understood by the public generally, nor by those likely to employ young engineers. Such a degree would be less valuable to the engineering graduates.

IV. The relative amount of work required for engineering and academic degrees.

As a general rule, the work required for graduation in engineering is considerably in excess of that in academic departments. Should a uniform elective system be extended to all departments of a university, the number of courses required for graduation would necessarily be the same for all degrees granted. In my own opinion this would not be desirable. If possible, an approximation to equal total work in the general and technical courses is highly desirable, since an excessive disproportion attracts the student's notice. Yet the objects, standards and methods in engineering education are so different that there can be but little attempt to conform to academic standards and requirements.

V. The last topic to be submitted is that of entrance requirements, where an elective system is adopted. As a general rule, an elective system means high entrance requirements, but with flexibility enough to allow the student to prepare himself for any subject in which he may desire to specialize. The general tendency seems to be to make the aggregate preparatory requirements the same for all courses. This aggregate is usually somewhat greater than the required number of courses in mathematics, science and language considered necessary for engineering students, so that, after these essential studies have been taken, the additional required studies may well be elective. After the necessary requirements have been met, the maturity of the student is most desired. This certainly can be secured by the study of any of a variety of subjects, from which the student should have the privilege of selecting.

In conclusion, it may be said that so many of the studies required in the engineering courses are preparatory to the professional studies that there is no room for electives except in the Junior and Senior years. Even in the last two years of the course the permissible variation from some one of the regular courses is so slight that the term "elective system" would be deceptive. However, enough electives may be allowed in the Senior year to offset most of the objections to a rigid course system and permit of a proper amount of specialization.

DISCUSSION.

PROFESSOR BULL wished to answer a small part of the very large question contained in the paper by saying that in his judgment it would be a benefit, as a rule, to introduce electives in the Senior year. If the college has sufficient means to employ a large number of instructors to teach various special subjects, he considered it a decided advantage to give the student a chance to make certain elections in the Senior year. He thought there ought to be no question, however, about electives in the Freshman and Sophomore years. In the speaker's opinion, it should not be made possible for a student to omit at his pleasure such subjects as, for example, calculus and chemistry, because he might not think these things were absolutely necessary. The speaker regarded such studies as essential to the engineering profession in every branch, and he therefore thought it best that the work for the first few years should be fixed; but that afterwards the student might be allowed to elect.

PROFESSOR H. E. SMITH said that at the institution with which he was connected, electives were offered in the Senior year, both in the mechanical and electrical engineering courses, and that the student was given a wide latitude of choice. Thus, if a man wanted to specialize in railroad engineering, for example, he could devote a large proportion of his time during the Senior year to locomotive or car designing.

PROFESSOR ALLEN said that he happened to have information about that subject in its relation to civil engineering. At the institution with which he was connected, three options had been provided in the Senior year, in which special attention was given either to geodetic, or to railroad, or to sanitary and hydraulic work. There were similar options in the course in mechanical engineering. By this means more or less liberty was given the student, although on fairly distinct lines, to shape his course in directions either attractive or likely to be specially useful to him.

Professor Sanborn thought that electives should be controlled in such a way that if a student wished to take a certain subject, such as machine designing, he should first have had preparations in certain other prescribed studies. That would necessarily limit the student's choice within definite lines. In this way a so-called elective system would really involve a large amount of prescribed work.

Professor Jacoby said that at Cornell University a limited amount of elective work is allowed in the Senior year. Two hours per week throughout the year are devoted to any one of eight courses offered, while three exercises per week for two terms are devoted to one of five elective laboratory courses.

Professor Hatt thought that the question of elective studies in a given course depends on the entrance requirements, which, in some schools in the East are so far in advance of certain schools in the West that it is possible for the former to present in the Freshman or Sophomore year technical studies which in the latter schools have to be postponed till the Junior or Senior year.

Professor S. W. Robinson thought there was great danger of carrying the matter of electives too far. He had known students who had been well equipped with elective studies, and when they had left college and entered life they had gone into other engineering lines, in which their special elective studies had been of little benefit to them. The speaker was satisfied that in some cases it is to the advantage of a man to take elective courses in the Senior year, but that in other cases it is distinctly to his disadvantage. He was inclined to believe that elective studies should not be permitted, except in rare instances.

Professor Caldwell agreed with Professor Robinson, and thought that there is, therefore, much in favor of arranging the engineering courses as nearly the same in the different engineering departments as possible, so that the graduate might be better fitted to devote himself to any line of engineering work that might offer him the best opportunities. Greater specialization can, of course, be carried on to advantage in post-graduate work.

Professor Reber thought it unquestionably desirable to offer electives in the Senior year. He was of the opinion, however, that students should not be permitted to elect in the Junior year, and he believed the tendency to be against this practice. No matter what branch of engineering the student may wish to follow, certain fundamental courses are necessary, and the differentiation should not be made too early. The speaker believed that the men who succeed best in after life are those who have been thoroughly grounded in general fundamental principles before they begin to specialize.

Professor Aldrich thought it would be hazardous to allow the student to choose many of his courses in the Freshman year, or to permit too much latitude with respect to electives. It seemed to him that in all cases there should be a definite character of work that the student should be required to take, while certain collateral studies might be safely offered as electives. In general, electives should, he thought, be arranged in groups of coördinate subjects. To allow a student, especially in his early years at college, to pick out, here and there, such studies as he pleased, would be a questionable policy from an educational point of view. The student would thereby gain only a smattering of education, without a thorough knowledge of anything.

Professor Allen wished to speak briefly with reference to what had been said by Professor Reber. The practice at the institution with which he was connected had been in direct opposition to the practice of Professor Reber. In the early days the work of the Freshmen and Sophomore years had been taken in common by the students in civil, mechanical and mining engineering. The selection of either one of these courses has now to be made substantially at the end of the Freshman year. In fact, an election is necessary between certain courses, as early as the middle of the Freshman year. The speaker thought it desirable that these facts should appear in connection with what had been said by other speakers for the guidance of those who should read the discussion.

Professor Reber did not wish to be misunderstood. While he was well aware of what Professor Allen had said, and granted that the past tendency had been towards the differentiation of courses, yet he believed that the time has come for a return to the more general engineering courses unless the requirements for admission are materially raised. If they could be made equivalent to at least two years of a general college course, specialization might profitably begin early. But so large an amount of the same fundamental work must be given in every engineering course, that it is questionable, even under this condition, whether the better training would not result from later differentiation. It is the common experience that the graduate of a given course finds cause for regret in his professional life that his work in college was not laid out on broader lines. After graduation he can far more easily supply deficiencies in special applications, than in fundamental principles.

Professor Eddy inquired whether Professor Allen could not state the considerations which controlled at the Massachusetts Institute in determining electives.

Professor Allen said that he was not fully prepared to do that. He thought it proper to state, in answer to Professor Reber, that in the civil engineering courses, as now differentiated, the students, at the close, have received more than a full year's instruction in advance of what had been offered when the earlier practice was inaugurated. The speaker regretted that he was not in position to state the causes that had led to the present policy. Individually, he was much impressed with the fact that very many subjects taught in engineering courses contain the proper elements for successful education, and a large degree of selection is possible without that injury to the student which would result from substituting studies in which the training element is not conspicuous. In fact, engineering courses are extremely rich in subjects which would be beneficial in almost any branch of after-life, and thus the opportunity for differentiating may be wisely permitted at an early date.

President Mendenhall said that the Society was very much indebted to Professor Jones for the interesting paper which he had read. He wished the indulgence of the meeting to say that in the institution with which he was connected the differentiation between civil and other engineering courses began at the middle of the Freshman year, which was the practice also at the Massachusetts Institute of Technology. In their own institution the shop practice differed considerably in amount and in character as between the mechanical and the civil engineering course after the middle of the Freshman year.

THE DESIRABILITY OF UNIFORMITY IN THE USE OF MATHEMATICAL SYMBOLS AND TERMS: AND HOW TO SECURE SUCH UNIFORMITY.

BY ARTHUR E. HAYNES,

Professor of Mathematics, University of Minnesota, Minneapolis, Minn.

If this brief paper suffices to give rise to a fruitful discussion of the subject of which it treats, or offers any suggestions of value in such a discussion, the object of its author will have been fully accomplished.

He is not unmindful of the tremendous difficulty of securing such a use of these symbols and terms; but he also appreciates, in some measure, the great advantage that such a reform would bring, and is not discouraged by the apparent defeat of the most commendable attempt which has already been made by the Society to accomplish a similar reform in the subjects of electrical, mechanical and civil engineering.

It seems to the writer (*a*) that such a uniformity is desirable; first, for the sake of clearness in mathematical discussions, and second because of the nature of mathematical science; and (*b*) that such uniformity may be secured by singleness of definition and by conventional agreement.

Under the first head (*a*) it may be remarked, that while it is utterly impossible, in ordinary language, for different persons to always use the same words and terms with a uniformity of meaning, yet in the science of mathematics this can be done. In ordinary language there are many ways to change the meaning of words, *e.g.*, by the tone of one's voice, by changes of the countenance, by the accompanying gestures, or by the use of italics; but in the science of mathematics the symbols and terms not being designed to express emotions, but scientific ideas, are not subject to any such accidental variations of meaning, and may therefore be employed in securing the uniformity advocated in this paper.

That the nature of mathematical science demands such uniformity is so plainly evident as to require no argument. Should not a science which is the very foundation of exact learning, and which furnishes the vehicle for conveying the ideas of all the other sciences where measurements are involved, be itself free from ambiguity in the use of its symbols and terms?

The writer proposes to point out a few cases of the ambiguous use of terms and symbols in this science, in the hope of helping to purge it from such defects. The following will suffice as examples:

The word 'cancel' is used, frequently in the same work, in the sense of the striking out of equal factors, and the striking out of numerically equal terms with opposite signs.

The symbol 0 (zero) is used to signify an entire absence of number and an infinitesimally small number.

In many works Naperian logarithms are said to be characterized by the modulus unity, while in others such logarithms are called natural logarithms.

Ratio is defined both as the quotient of the antecedent divided by the consequent, and the consequent divided by the antecedent.

The symbol for multiplication (×) is said to mean 'times,' 'multiplied by' and 'into,' some of which meanings are incorrect, if the multiplier must be an abstract number.

The term parameter is used to signify the double ordinate through the focus of a conic section, and, again, as 'an arbitrary constant entering into an equation of a locus, but which is made variable by hypothesis.'

The base of a system of logarithms is symbolized by e, as is also the eccentricity of a conic section.

The word 'decimal' is used with two meanings.

Even the word 'sum' is used with a double meaning. While in most cases it is used to signify the aggregate, yet it is also employed to indicate the limit of the sum, as is the case in dealing with an infinite, decreasing geometrical progression.

The word 'limit,' as defined, generally excludes the number toward which it constantly approaches, but sometimes it does not.

The word 'pole' as used in analytical geometry, and as used in the theory of functions of a complex variable, has entirely different meanings.

The word equal, as used in different works on geometry, is applied to figures having the same magnitude and form, or to those having the same magnitude and unlike form.

Quadratic equations, involving both the second and first powers of the unknown quantity, and those involving only the second power of the unknown quantity, each have at least two names.

While the Greek symbol (π) is used to express the ratio between the circumference of a circle and its diameter, and also to signify the product of an infinite series of factors.

Spherical degree, as used in geometry, is an objectionable term, for it signifies area rather than difference in direction.

The foregoing are sufficient to suggest the desirability of an elimination of such Janus-faced terms and symbols from the science, and the necessity for uniformity in the use of mathematical symbols and terms.

It may be argued that the context removes, in most cases, the cause of any misunderstanding, and that it would be unwise to introduce more symbols or terms where now one is used in more than one sense.

While the writer believes that this argument might seem valid in the case of more mature students of the subject, yet upon the whole, when those who are practically beginners in the subject are also considered, he is of the opinion that the added clearness of discussion caused by the change advocated will much more than compensate for the necessary increase in the number of terms and symbols that such a change would require.

Under the second head (*b*), the suggestions offered with reference to singleness of definition and united action on the part of those interested, seem to be the best available means for securing the reform herein discussed.

In conclusion, the writer respectfully and earnestly suggests that the Society request the American Association for the Advancement of Science and the American Mathematical Society, at their coming meetings, to each appoint a committee to act with a committee from this Society, in inaugurating and carrying forward this reform, by seeking the active coöperation of all similar organizations throughout the world.

DISCUSSION.

PROFESSOR WALDO thought it well enough to inquire whether there was any prospect of a practical outcome to the questions raised by the author. Everybody, he said, recognizes the difficulties pointed out in the paper, but it seems unprofitable to dwell upon the subject, because there is no way of carrying out the suggestions made, and in fact, no chance of accomplishing anything in that direction.

PROFESSOR EDDY thought the matter too complicated for securing uniformity; that a similar attempt had been made in electrical branches and had signally failed. The speaker declared that such efforts had always been fruitless; that it is impossible to bring into line everybody who wishes to write a text-book and compel him to use a fixed set of symbols. While there might be a general acceptation of certain symbols, that can not be accomplished by the action of societies.

A CONVENIENT LABORATORY EQUIPMENT FOR THE STUDY OF DIRECT CURRENT DYNAMOS AND MOTORS.

BY HAROLD B. SMITH,

Professor of Electrical Engineering, Worcester Polytechnic Institute,
Worcester, Mass.

In a short paper presented at the Boston meeting of the Society, a year ago,* the writer outlined briefly a plan of electrical engineering laboratory organization which was believed to contain several important features by means of which the equipment of such a laboratory could be made most effective for work of instruction. On account of a number of inquiries regarding the details which make such a plan possible, it is thought that the following description of an equipment, which is typical of several to be found in the dynamo laboratory of the Worcester Polytechnic Institute, may be of general interest.

The equipment to be described is designed in such a way as to provide for practically all lines of experimental work encountered in laboratory instruction with direct current dynamos and motors. At the same time the system of connections is so simple and flexible that the value of the apparatus for any one piece of work is not impaired because of its applicability to many other lines of experimentation.

Two 18-kw. machines designed by the writer and manufactured by the Elektron Manufacturing Company, of Springfield, Mass., are directly connected by a clutch, pulley, or preferably, by a magnetic clutch coupling which would also be available for tests on such a device. Both machines have standard armature windings as regularly manufactured for the market, but are provided with special field windings. One machine is for 550 volts, and the other is for 125 volts. The shunt windings have about 50 per-cent more copper than usual, so that for a short time more than double the usual number of ampère turns may be impressed on the magnetic circuit. The series windings have about double the usual amount of copper, so that shunts may be provided to secure various percentages of compounding, and so that the main shunt circuit may be thrown out entirely and the machine operated as a series motor when desired. The shafts project beyond the bearings at the commutator end of the machines so that absorption or transmission dynamometers, couplings or pulleys may be applied to either machine, and the machines loaded by any one of several different methods as may be desired for different experiments.

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* Note on the Organization of an Electrical Engineering Laboratory, Proceedings, Vol. 6, p. 49.

Each circuit of each of the machines is brought to terminals on a special switchboard, so that the student having occasion to use the machines, finds them entirely disconnected ; but, by means of taper brass plugs at the ends of flexible switchboard cable, he is able to connect the brass terminals on the board with no loss of time, provided he understands the theory of his experiment. If he does not understand what he is doing, he usually produces a short circuit or otherwise fails to operate the machine and then studies out the theory of his connections. After one or two experiences of this sort, he comes to the laboratory with a knowledge of his experiment that enables him to make his connections promptly, correctly and without the assistance of an instructor.

In series with each armature, and before the circuit reaches the terminals on the board, is placed a circuit breaker which protects the armature and incidentally surprises the student into a thorough appreciation of its function and value as a protective device when he attempts to start the machine as a motor with the field circuit open, as is usually attempted, at least once, by each student in the early stages of his training. Around each of the shunt circuits is placed a high-resistance graphite pencil to take the inductive discharge should the shunt circuit be broken at full excitation, and, before reaching the terminals on the board, a fuse is placed in the circuit, so as to protect the winding from excessive current. The series circuits and the instruments on the board are also protected by fuses, so that faulty connections on the part of the student involve so much time spent in replacing fuses that there is a strong incentive added to his natural or acquired inclination to do careful, systematic work. The blowing of a fuse or the opening of a circuit breaker serves the double purpose of protecting the apparatus and notifying the student's sharpest critics, his fellow-workers, of a faulty connection or careless work.

For each machine is provided a field rheostat of the enamel type and of greater range of resistance values than usual; also a starting resistance with underload release which may be connected into the armature circuit.

Suitable lines run from the switchboard at the machines to a general supply and distribution switchboard where connections can be made for supply of current, to additional instruments or to any pieces of apparatus in the entire laboratory equipment desired for any piece of experimental work.

An experience of several years with this type of equipment has shown that the apparatus is not injured by ignorant or careless students, that the student can be thrown entirely upon his own resources when working with the machines, that he must understand the theory of his experiment before he can manipulate the apparatus successfully, that the equipment is extremely flexible and applicable to different experiments and, finally, that the time and attention demanded of the instructor is materially reduced.

THE RELATIVE DISTRIBUTION OF THE INSTRUCTING FORCE IN COLLEGIATE DEPARTMENTS.

BY JOHN P. JACKSON,

Professor of Electrical Engineering, Pennsylvania State College,
State College, Pa.

The relative number of instructors in the different departments of engineering colleges is exceedingly varied. This probably results from two causes : first, the personal equation as affected by the heads of departments, and second, the fact that there is little suitable data available for indicating, or for assisting in determining, the proper proportions.

College instructors may be conveniently ranked in three classes. In the first may be placed all those heads of departments who are exceptionally energetic, especially in building up, developing and extending their own lines of work. To the next class may be assigned men who are energetic in the performance of their duties, but who do not give much attention to the growth of the departments under their charge. And, finally, a class must be added of those professors who perform only the duties assigned them under their contracts, leaving questions of department or college development to others.

Even where the most efficient corps of instructors is found, some of the men are certain to excel in executive ability and other qualifications required for the development and growth of collegiate or university work. Such men will naturally be able to obtain from college presidents or executive boards, additions to their teaching force, apparatus, etc., more readily than will their colleagues. The fact that unequal distribution is often made from such a cause is well known to every member of the Society. The college president has very little basis other than the arguments presented to him by the professors, for determining the most just and equitable distribution of the instructing force. He may study the catalogues of sister institutions and obtain some general idea of what is elsewhere considered for the best interest of all departments, but even though he use the greatest care in such an examination, the variety of results obtained will leave him with little useful information. The matter thus resolves itself largely into a question of local influence and conditions, so that the opinions of the energetic, enthusiastic professor are quite likely to be given undue weight.

Such a state of affairs is apt to strengthen one or more departments of the college to such an extent as to detract materially from the value of the others. For instance, it is not uncommon in colleges offering undergraduate work in classics, literature, modern languages, science and engineering, that an excess of aggressiveness on the part of either the technical or non-technical members of the faculty will cause an undue development along engineering or literary lines, thus seriously weakening the institution in vital points. It is not intended, of course, to intimate that development in every department should not be made as rapidly as is consistent with the conditions, but rather to emphasize the importance of equalizing that development throughout all lines of work. In considering the engineering school by itself, it will be found that quite frequently one course has a relatively much greater development than the others, thus destroying the proper equilibrium. The difference may be in equipment, buildings, or in other features; but it is almost always accompanied by an undue relative increase in the number of department instructors.

To indicate how variable American practice is in regard to this matter, the writer has taken the catalogues of ten leading colleges and universities giving strong engineering courses, and has made the following tabulation of the relative number of instructors in the departments of mechanical, civil and electrical engineering. In this table, the number in electrical engineering is called 100 per-cent and those in the other two courses rated accordingly.

Designation of Institution.	E. E. Course.	M. E. Course.	C. E. Course.
No. 1	100	160	160
" 2	100	80	80
" 3	100	150	100
" 4	100	200	100
" 5	100	150	200
" 6	100	100	130
" 7	100	250	100
" 8	100	150	300
" 9	100	100	200
" 10	100	175	150

It will probably be said that the differences shown in the table are due largely to the kind of training called for in the section of country from which each institution draws its students. This would be a natural inference if the largest classes had relatively the greatest number of instructors, but this is not borne out by the facts. In making the tabulation, instructors in shop-work and elementary drawing were not credited to the mechanical engineering courses, and other instructors, who give part of their time to non-engineering work, were given only a fractional credit. It is impossible to prepare a perfectly accurate tabulation of this kind from the study of catalogues, on account of work overlapping more or less; but the results are close enough to give an approximately true view of the subject.

It is noticed that the ratio of the teaching force between mechanical and electrical engineering varies from 80 to 250 per-cent, and that the ratio between civil and electrical varies from 80 to 300 per-cent If the departments of modern languages, English, mathematics, chemistry and physics had been included in the tabulation, the variations in the several institutions would have been found to be still more marked. The number of instructors in a course does not seem to depend to a very large degree upon the number of students enrolled. In fact the variations of numbers of students and relative numbers of instructors were found to be so erratic as to indicate but small relation between these two factors. The ratios given are doubtless largely the result of the relative personal aggressiveness of the heads of the departments.

The question is one of serious importance to a school of engineering, not only from the standpoint of an equitable distribution of the instructing force among the engineering departments themselves, but also as bearing upon the general preparatory work of the first years of a college course. For instance, grave injury may readily be done the engineering work, if, say, the chemical department has been unduly developed, since this must necessarily be done at the expense of other work.

Data which would give the average practice of American colleges in this regard should prove of great service to the faculties and the presidents of institutions offering courses in engineering. In this paper, the writer merely desires to call the attention of the Society to present conditions without even suggesting a scheme for properly controlling the distribution of the instructing force, or attempting to present information which would be of service for that purpose. The data for such a scheme could only be obtained through the medium of an officer connected with each institution. Results gathered in this way would have the advantage of coming directly from persons knowing all the peculiarities and local conditions by which they are affected. The gathering of such data and its formulation into useful shape can be done only by an association of representative technical college men.

DISCUSSION.

PROFESSOR JACOBY considered it rather difficult to discuss the subject because there was no indication in the paper of the character of the several courses. It is a well-known fact that recitations require much smaller classes than drawing and lectures; again, in certain laboratory courses, fewer students can be handled in a body than in field work. In the speaker's judgment little information can be gathered from such tables unless more detailed information is given as to the character of the courses, which had much more influence upon the number of students per instructor than anything else. Furthermore the speaker thought the reason assigned by the author insufficient to account for the facts presented.

PROFESSOR WALDO thought one essential thing had been omitted in the construction of the table, namely, the geographical distribution. For instance the institutions designated as Nos. 2, 6 and 7 show specialization in different directions. In one there is an excess of electrical engineers as teachers, in the second of civil engineers, and in the third of mechanical engineers.

If these three institutions are near enough together to draw largely from the same constituency, and if one deliberately strengthened one department, a second another, a third still another, this distribution of function would be wise and highly commendable. Other circumstances can be imagined where it would be just the reverse. The table in its present form gives no basis for discussions of this character.

PROFESSOR MARBURG said that he had been keeping statistics for some years of the attendance in the several engineering courses of many institutions. The ratio between the totals for different courses in a given college is often quite considerable. Not infrequently it is so marked that, while the classes in one course might be handled in a single body, in another they would have to be divided into sections for effective instruction. In the latter case, the staff has to be increased correspondingly, although this might be in no way indicative of greater favors shown to one department than to another. It seemed to the speaker that, in the absence of accompanying statistics, relative at least to the number of students, no conclusions could be safely drawn from the figures presented.

Professor Allen considered it a very difficult matter to construct any table which would accurately represent the comparative work done by instructors in different courses and in different colleges. At the institution with which he is connected, one of the teachers in the civil engineering department, gives instruction in hydraulics to a greater number of students in mechanical, and in electrical engineering than to students in his own department. Students in mining engineering receive all their instruction in surveying from members of the department of civil engineering. The professor in charge of the department of mechanical engineering appears in the catalogue as "Professor of Applied Mechanics." The speaker had recently attempted to determine the amount of time spent by various members of the faculty in their special lines, and had failed to acquire satisfactory results from data vastly superior to that contained in the catalogue. Under such conditions it would be futile for any outsider, for the purpose of making a tabulated statement, to attempt to determine what force should be given to data secured from catalogues.

Professor Mees observed that the trend of the discussion suggested something that he was afraid would never be realized, namely, that in the study of such questions we might safely appeal to the catalogues. He thought it unnecessary before a meeting of college professors to make any comment on what that meant. It is well known that the ordinary catalogue does not disclose exactly what work each professor is engaged in, or how much time is allowed to each study. The speaker had endeavored to gather statistics with a view of making a comparison between the time allotted to different subjects at various colleges, and the amount of work done by each professor; but had had to give it up as a Chinese puzzle. He believed the only way in which reliable data could be gathered upon such subjects was to get them directly from some one identified with each particular institution. He had tried to compile such data for his own institution by going back to the earlier catalogues, and he had found it almost impossible. The speaker believed that valuable and exceedingly instructive results might be obtained, if such data were collected for the various colleges in the manner suggested, and the results tabulated and laid before the Society.

THE ESSENTIALS OF A TECHNICAL EDUCATION.

BY ARTHUR L. RICE,

Professor of Steam Engineering and Applied Electricity, Pratt Institute, Brooklyn, N. Y.

In the broad and ever-extending field of designing, manufacturing and construction, grades and degrees of skill are required varying from that of the factory-helper to that of the engineer in charge. For each grade a different kind of ability and experience is required, obviously of small amount in the lowest grade, and as broad and varied as possible in the highest. In the lowest grade, the daily experience of the laborer is generally sufficient training and, as the thinking is done by those in charge, no education is necessary. For the engineer, the best training, both in practice and in theory, is being developed in a satisfactory manner by the colleges devoted to that work. Between these extremes are the superintendents, foremen, draftsmen, skilled mechanics, etc., men whose positions demand considerable knowledge, experience and ability; but not necessarily the qualities of the engineer. Their work is the development and execution of designs already made; or the adaptation, changing and combination of such designs to fit new conditions. As examples may be cited, the erection of steam and electric plants, and the alteration of standard forms of machinery to meet special requirements, for which only simple details need be changed. The requisites for the successful conduct of such work are a knowledge of the facts and details of practice; of methods of doing work and their comparative values; and the ability to devise details and execute them. Such a knowledge of the first principles of mathematics and science as will enable a man to understand the reasons for methods and details of practice is also needed. Anything further is desirable, but cannot be considered as indispensable. At the present time, this grade of work is done either by men who have had only the training of the shop which, unless supplemented by study, must be narrow and without a sufficient scientific basis; or else by men who have had a full engineering college course, a training more extensive and costly than is needed for the work in view.

Of the requisites mentioned, the knowledge of facts and details of practice must come largely from experience. In no course of instruction, of reasonable length, is there time for imparting such knowledge as such; besides, the details in various lines of work are so different as to call for specialization in each line. The only possible hope of success in that direction would seem to lie either in separate trade-schools for each particular industry, or in apprenticeship systems conducted by individual corporations.

For a technical school, the proper lines of effort are the teaching of methods and principles, and the development of ability to think and execute. Adequate training for such work as has been mentioned can be best furnished by short courses which will be available for a greater number than are the regular engineering courses; both because, being shorter, they will be less expensive, and because they will require less preparation for admission.

In such technical training, the acquirement of practical details during the course is desirable; but, on account of the limited time, this must be combined with the thought training. It may be accomplished in part by the use, in the teaching of science and mathematics, of concrete examples and illustrations, with data drawn, as far as possible, from the daily surroundings of the shop and drawing room. Instruction in methods of work and their adaptation to differing conditions should be given by extensive shop and laboratory practice in which the thought element should be introduced by placing the student on his own responsibility as rapidly as his experience will permit, and requiring him to devise methods of doing work and experiments. To drive home the knowledge gained and to teach the student to make use of what he learns, the work should be so planned that the performance of advance exercises necessitates a knowledge of preceding ones.

Problems assigned in the laboratory should be, as far as possible, those of actual occurrence in practice and involving the demonstration of natural laws. For example, the variation of H. P. with valve-travel or load may be worked out in the laboratory in connection with the teaching of the use of the indicator and planimeter. Shop exercises should involve operations which occur in construction, and the pieces made should be, in so far as practicable, parts of machines. Vacation work should be laid out along the same lines. It should be designed to give familiarity with practice, to require thought and the application of knowledge already gained.

By such means the essentials of a technical education, founded on a common school preparation, may be imparted in a period not exceeding three years, and, in many cases, the time may be reduced to two years.

A CATALOGUE AND CLIPPING CASE.

BY WM. T. MAGRUDER,

Professor of Mechanical Engineering, Ohio State University, Columbus, Ohio.

Much of the success of the professional man of to-day, who is consulted either by his students or his clients, depends upon his ability to instantly refer to cases, produce evidence, quote facts, and illustrate by blueprints and photographs, that information which no one expects him to always carry in his head. The lawyers have their way of reporting cases reduced to a better system than their less numerous and wealthy brethren of the clerical, medical and engineering professions. In the law, all cases coming before the higher courts are reported and then cross-referenced by subjects. The case with the engineer is totally different, and the nearest that he can at present come to the practice of the legal profession is in the use of the "Engineering Index," which, while extremely helpful, is but an abridgement, and raised to the n^{th} power.

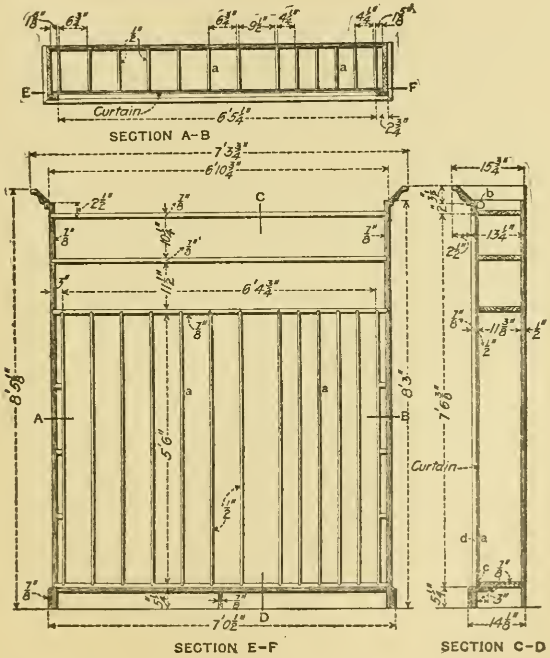
As the day of the always up-to-date engineering encyclopedia has not yet arrived, the engineer is forced either to be his own walking encyclopedia, or else adopt some method of filing, in as accessible a form as possible, the vast amount of information which is daily presented to his attention in the daily newspaper, the trade journal, the magazine, the trade catalogue and the transactions of the numerous professional and semi-professional societies.

The teaching engineer is less fortunate than his colleague who is consulted only by clients, because the former has to try to keep himself posted on a greater variety of subjects. Such men especially, therefore, need a method of filing and keeping clippings, catalogues, patents, lecture notes, references, reports, and data of all kinds.

An efficient method for doing this requires that it shall demand the smallest expenditure of time for filing and removing the articles; that the articles shall be as easily and as quickly accessible to the novice as to the constant user; that the contents shall be of easy removal, separately or by subjects, for use in the office, the lecture or drawing room, for filing under new titles, or for relegation to the waste-paper basket. The cabinet or case should provide a properly titled place for every subject in which its owner is likely to be interested; convenient in size to fit all standard sizes of catalogues, and all clippings without excessive folding; should be dust-proof, and should permit of unlimited growth with the least expenditure of time and money.

Having passed through all the stages of development from the cheap scrap-book system to the envelope, box and drawer system, index rerum, card catalogue and the like, and having just started to fill Volume II of the second edition of his catalogue and clipping case, the writer is desirous of explaining to the members of the Society, by blue-print and photograph (and by the thing itself to those who may desire to inspect it in his office), what he considers to be the most complete, accessible and elastic system which has as yet been presented. It is also one of the cheapest in first cost, so far as is known, for the facilities provided. Furthermore, as there is no patent or copyright connected with it, any one is welcome to have his carpenter build one for him from the illustrations herewith.

As a piece of office furniture, it resembles a bookcase over whose shelves a Scotch holland, shade-cloth curtain has been drawn. This gives a neat appearance when the curtain is down, and makes it practically dust proof. The spring curtain roller, 1½ inches in diameter, is hung in sockets above the top shelf. The lower slat is guided in a groove at its ends, and so prevents the curtain rolling up other than straight.



As the curtain runs between the outside casing and the wooden uprights, it makes the case as nearly dust-proof as is necessary. If security and absolute cleanliness is required, the method of the roll-top desk may be substituted. The writer prefers Scotch holland to opaque goods, because it is less liable to be creased and broken. He also prefers not to trim the edges, as a selvaged edge wears better. Unless the edges are to be trimmed, the goods should be procured first, and the case designed to fit the goods, as the goods are sometimes four inches wider than the normal width.

On rolling up the curtain by a touch of the finger, it will be seen that the case consists of ½-inch wooden uprights with saw-kerfs cut in same, ⅛ inch deep and one inch apart. By inserting bright tin shelves, divisions or pigeon-holes are made, one inch high, or multiples thereof. If greater economy of vertical space is desired, the saw-kerfs may be closer together. The saw-kerfs should be made by a thin bladed back-saw. The front edge of the tin shelf should be turned over and back upon itself for strength, to prevent cut fingers and to retain itself in the saw-kerf. Tin is preferable to wood because it is much cheaper, takes up less room, is flexible and does not split when removed. The distance between the wooden uprights is immaterial, because when the space is so great (10 inches or more) that the tin is no longer sufficiently stiff, galvanized iron can be used. The writer finds that from a sheet of 20 x 28-inch tin, shelves may be most economically cut to fit uprights which are 4¼, 6¾ or 9½ inches apart. The first width is used for clippings, notes and memoranda; the second for catalogues, folded blue-prints, letters and transactions; and the third for blue-prints and larger catalogues. Catalogues wider than 9 inches must go by themselves on one of the upper wooden shelves. Fortunately their number is small. The title of a division is written or printed in a space $\frac{5}{16}$ wide by two inches, bent at right angles on the end of a piece of paper 2x5 inches. A title slip is placed on the top of each tin shelf and under its own clippings. The titles are arranged alphabetically.

In making notes, in reading trade or technical papers, or on the receipt of a catalogue, the title under which it is proposed that it shall be filed should be underlined or written on the face of the paper. It should be divested of all excess of margins and outside covers. Clippings should be folded as few times as possible, depending upon the depth of the case; but should always be folded so that they can be filed with their titles uppermost, and so as to be seen and read as soon as withdrawn.

When inserting clippings, etc., in a case for the first time, it is well to leave at least one division vacant in each four or five for subsequent growth. Then, when more room is needed, the tin shelf directly over the crowded division may be removed and a two-story division obtained. The writer has one division $4\frac{1}{2}$ inches high. Or, the matter may be reclassified and so subdivided. Eight years ago the writer built a small one for himself, and three for friends, and outgrew his own; then, three years ago, he built one with four hundred and seventy-three divisions, each $1\frac{1}{2}$ inches high, and with twelve linear feet of shelf-room, at a cost of about 8 cents a division, and having packed it full, he has just rearranged his collection of clippings, notes, catalogues, etc., in the old one and in a new one which contains seven hundred and ninety-two divisions one inch high, and twelve linear feet of shelf room, and which cost about 5 cents a division.

It is impossible to express the comfort obtainable from such a piece of furniture, and from the feeling of being able to instantly put one's hand on all the data he has on a given subject outside of bound volumes; or, what is still better, to be able to send a student to it, and feel confident that he can instantly find what he is sent for. The writer would not think of returning to any single system which requires paste-pot, envelopes or drawers. Time and space are too precious, even in a professor's office, for such abuse. For small collections of notes which can be made on cards, the card catalogue is most valuable; for the record of a certain case or subject on which one is working, and which he wishes to refer to frequently, drawers, boxes and envelopes are useful in their place, and are all used by the writer; but for caring for piles of catalogues, or copies of transactions, 6 x 9 in size, and from 1 to 7 inches in height; or for a collection of from one to one hundred clippings, on from one hundred to one thousand subjects, he prefers the use of the above described catalogue and clipping case adapted to the particular needs of its owner, and trusts that it may be found helpful by other members of the Society.

DISCUSSION.

PROFESSOR H. E. SMITH described a filing case at the university with which he is connected which consists of shelves on which are placed pasteboard boxes, open at the back and reinforced in front by a piece of tin, numbered consecutively. The case contains also a few drawers for cataloguing cards showing the contents of the boxes by an appropriate system of numbering and cross-referencing. The advantage of such a case is that any box can be removed at any time to the drawing-table or desk for purposes of reference. The boxes are practically dust-proof, as the back of the case closes the boxes when in position. Another advantage is that the system is capable of convenient expansion to an indefinite extent. The speaker said that the cost of these boxes was about 13 cents each; that they were made in three sizes, 7 by 10, 8½ by 11½, and 10 by 13, and from 2 to 2½ inches thick. Each catalogue or clipping is stamped with the words, "Please return to case No. —," the number being supplied by means of another stamp.

Professor Jacoby considered the subject of the paper a very important one, especially to teachers of engineering. He, himself, during the past twenty-one years, had passed through all the stages of development in the filing system which Professor Magruder had indicated. The question of the relation of one subject to another had been a particularly perplexing one. In the speaker's opinion, the arrangement of the material should accord with the relationship of the subjects, and should not be determined alphabetically. After trying various systems, he had finally adopted what is known as the Dewey classification, which had already received very general adoption at different institutions of learning. By this system, all subjects related to one another can be readily grouped together, and can be readily found under certain general heads. On the other hand, by the alphabetical system it is often very difficult to give a definite working-title to a subject. The speaker used what is known as the business man's cabinet file; with compartments or cases usually 3½ inches thick and about 10 inches wide and 12 inches long. He also used what is known as the monthly index, having the numbers 1 to 31 on the marginal tags. On the cover of the index, a strip of paper, three or four inches wide, is pasted by the corners, and on this are written the topics and their subdivisions with references to the corresponding numbers on the tags. By properly indenting the lines, the relations of the different subjects are shown. This list of topics may be rewritten when experience requires it.

References to bound periodicals or books are made on thin slips, three by five inches, the subject, author, and reference being placed in separate lines. These slips cost only twenty cents for 500, being much less expensive than those required for a card catalogue. Many years ago the speaker learned how to make a very condensed reference to any small but important article which is found on the same page with many others, and which may not even be furnished with a title. Thus, Eng. News, $29/433^{17}$ indicates a reference to a paragraph in *Engineering News*, volume XXIX., page 433, first column and seven-tenths of the way down the column. Special attention was called to this expedient as it had proved to be a most valuable timesaver.

Professor Sanborn said he had been working upon this matter of preserving clippings for some time. The objection to the filing-case of Professor Magruder, which appealed to him quite strongly, was the size of the case and the trouble of removing it when it became necessary. It appeared to him that a system of units, such as is used in book-cases made by the Wernicke Company, could be adopted to advantage. He suggested that because he had seen Professor Magruder's case, and it is really quite a monster.

Professor Allen said that nearly everybody was familiar with the card catalogue, and many people thought it indispensable in matters of this kind. He believed, however, that the card catalogue does not, in all cases, provide the most convenient index, for it requires an appreciable interval of time to pass from one card to another, and a great deal of time is often necessary to run through a number of cards on a given subject. A sheet of paper, about 6 by 8 inches, with a half-dozen different titles, offers some advantage over that number of cards, especially in rapidity of use. Such sheets can be bound together in a fashion which will allow a sheet to be detached, and one or more new sheets inserted in its place. Even taking into account time spent in occasionally renewing sheets, this system will in many cases secure greater economy of time than the card catalogue, although the latter is in many cases practically indispensable.

Professor Magruder wished to ask Professor Jacoby what he would do in case he wanted to file a certain clipping on some new and important sub-division of a subject, and his case was already filled, according to the scheme drawn up before this new sub-division existed.

Professor Jacoby said that some divisions would of course be filled more rapidly than others, but that it is a very easy matter to eliminate one topic if desired, or to insert another, although this involves necessarily some rearrangement. That is the more easily accomplished because in a number of cases the spaces would be found entirely vacant. The aim should be to rearrange the material as it accumulated to best satisfy the space requirements. The speaker had used that method of filing for eleven years with very little change and had found it extremely satisfactory. At Cornell University, they were encouraging their students to file away material which might in after-years prove valuable. The speaker valued the material which he had preserved in that manner, more highly than that part of his library which consists of bound volumes, for the reason that it could not be replaced in case of loss by fire.

Professor Magruder said that the particular merits which he claims for his filing-case are the ease with which the indexes can be consulted and the facility with which any subject can be found. These features are especially important when a student is s[illegible] to consult the files unaided. Another advantage is that little or no room is wasted in the case. The spaces are of three different widths: hence there is no need of using a big box for small papers.

The speaker acknowledged the validity of the objection that the case was large; but stated that his collection of catalogues and clippings could no longer be filed in one small case, and that, therefore, he had had a second case built. The cases had been designed so as to go through the ordinary doors of public buildings, and they can be crated and easily transported by freight. The cases are in no sense "monsters." If smaller units are desired, the same principles can be applied, and a knock-down case can be built, any section of which can be carried by one man; but the cost will, of course, be greater. In this form it will commend itself to railroad officials and to travelers.

President Mendenhall wished to say a word with reference to the system of labeling which seemed to him the most objectionable part of the scheme. During the last three or four years he had had occasion to temporarily arrange several thousand pamphlets somewhat on the plan described, and that had been a great source of annoyance, because when he wanted a pamphlet, he invariably found it at the bottom of the pile, and its removal displaced the label. He said that it seemed to him that that is a serious objection to the system advocated by Professor Magruder.

Professor Magruder remarked that the President's experience had been the reverse of his own.

President Mendenhall said that there was one other point, not bearing directly, however, upon the subject of filing-cases, concerning which he thought he would find a bond of sympathy with his hearers, namely, the frequent absence of titles on the backs of college catalogues and other pamphlets. To his great annoyance he often found himself compelled to go to the trouble of supplying such omissions for facilitating reference afterwards.

DRAWING, SHOP WORK AND ENGINEERING LABORATORY PRACTICE IN ENGINEERING COLLEGES.

BY HARRY E. SMITH,

Assistant Professor of Mechanical Engineering, University of Minnesota, Minneapolis, Minn.

The amount of time devoted to the subjects of drawing, shop work and laboratory practice in the engineering courses of some of the prominent technical colleges of this country, varies to a marked degree. In making a comparative table, for use at the University of Minnesota, the writer was impressed by this disparity of time allowed the above subjects, and the results were so striking, when arranged in a graphical form, that they were believed to be of sufficient interest for presentation to the Society.

The subject has already received a somewhat extended consideration, notably in the articles published in the *Engineering News* of the years 1892 and 1893, and also by Dr. Thurston, in his paper on *Technical Education in the United States*, which was read before the American Society of Mechanical Engineers, at the Chicago Meeting in 1893. If any apology is needed for the appearance of this paper, it is to be found in the general experience that the information given in the above papers is of too general a character for satisfactory comparative purposes.

The material used in making the charts herewith presented, was obtained from the latest catalogue of each institution, and has been recently submitted to the departments concerned in each technical college, and the figures were approved or modified, except in a few cases in which no replies were received.

In the construction of Charts I. and II., the horizontal distances represent weeks per term and the vertical distances, hours per week given to each subject. In order to make the charts more easy of interpretation, figures have been placed at the base of each rectangle, showing the length, in weeks, of the working term or semester; and also figures at the left-hand end of each rectangle, showing the number of hours per week given to the subject. The length of term given is not intended to include time taken up by term examinations, nor the work in connection with the preparation of the final thesis.

No attempt has been made to specify the exact branch of the study connected with the work, further than the three general classifications: drawing, shop work and laboratory practice, which are distinguished by a system of cross-hatching on the charts. Where one of these divisions of the work is taken up in connection with two or more studies, separate division of the space is made by lines. To illustrate: in the Sophomore year of the mechanical engineering course at Cornell University, there are 6 hours per week given to mechanical drawing and 2 hours per week devoted to drawing in connection with the study of descriptive geometry. It has been the endeavor to include all drawing-room work of each course without regard to the subject with which it is connected.

In the case of laboratory practice, only the work given in the mechanical or electrical laboratories has been shown; the elementary physical or chemical laboratory work having been omitted in each case. This division of work between the physical and electrical laboratories is not well defined in some of the colleges, and in these cases the writer has been guided by the synopsis of the work as given in the catalogues of such institutions.

The work of each year of the courses has been grouped together, a slightly wider space denoting the division of these groups. Where summer or vacation work is made a part of the course, it has been indicated by the more extended vertical rectangles which are placed in the spaces dividing the years of the courses.

The following tables have been compiled from the charts, and give the total number of hours devoted to each subject, in each of the four years of the courses. Where summer work is demanded, it has been included in the previous year's work.

These figures have also been represented graphically in the accompanying Charts III. and IV., which show the total relative amounts of time given to each division of the work in the several institutions.

It will be noted that, in the mechanical engineering course at Cornell University, with the exception of an elective of from five to eight credits, the third term Senior year is wholly given up to the preparation of the thesis and, in the electrical engineering course, the time of this term is largely so spent.

The first two terms, only, of the courses at Columbia University are shown, as it was impossible to determine with sufficient accuracy the division of time between the several subjects. The time devoted to the

MECHANICAL ENGINEERING COURSES.

TOTAL HOURS.

COLLEGE.	DRAWING.					SHOP WORK.					ENGINEERING LABORATORY.				
	YEAR.					YEAR.					YEAR.				
	1	2	3	4	Total.	1	2	3	4	Total.	1	2	3	4	Total.
Cornell.	315	280	210	150	955	315	315	315	225	1170			262	250	512
Columbia.						240	380			620					
Illinois.	386	247	91	325	1049	330	247			577			265	138	403
Iowa State.	141	186	141	204	672	241	241	241	241	964			93	372	465
Lehigh.	205	102	205	544	1056	84	168			252	72		51	102	153
Mass. Inst.	225	195	165	135	720		90	150	185	425			30	120	150
Michigan.	202		160	166	528	165	290	85		540			48	240	288
Minnesota.	178	242	231	242	893	198	286	198		682			154	286	440
Purdue.	266	136	265	228	895	333	333			666			114	152	266
Wisconsin.	132	210	368	332	1042	260	108	246	278	892			142	320	362
Worcester.	90	210	120	180	600	543	468	468	150	1629				330	330

ELECTRICAL ENGINEERING COURSES.

TOTAL HOURS.

COLLEGE.	DRAWING.					SHOP WORK.					ENGINEERING LABORATORY.				
	YEAR.					YEAR.					YEAR.				
	1	2	3	4	Total.	1	2	3	4	Total.	1	2	3	4	Total.
Cornell.	315	280	210	125	930	315	315	315	225	1170			262	375	637
Columbia.						70	70			140					
Illinois.	386	247	91	129	853	330	217			577			238	120	358
Iowa State.	141	186	45	231	603	248	248	128		624			93	186	279
Lehigh.	204	102	34	136	476								272	323	595
Mass. Inst.	225	125	75		425		90			90			30	270	300
Minnesota.	176	242	220	132	770	198	286	198		682			198	242	410
Purdue.	266	136	176	204	782	333	264			597			24	240	261
Wisconsin.	198	210	144		552	273	108	90		481			382	354	736
Worcester.	90	120	129	180	510	513	468	468		1479				390	390

laboratory work in the electrical engineering course of this college in the third and fourth years is not prescribed, but a definite number of experiments are required to be worked and reported upon. The average student, it is reported, spends about 12 hours per week in the laboratory on this work.

The shop work in the mechanical engineering course at Lehigh University, is entirely replaced by summer visits of inspection, and the time so spent has been shown by unshaded sections in the charts.

Owing to the proverbial indefinitness of the modern college catalogue, it has been exceedingly difficult to gather the data presented. This difficulty in tabulating the courses of many of the leading universities, as Stevens Institute, Ohio State University, and others, has made it necessary to omit them in this paper; but it is believed that the figures in the cases under consideration are very close to the actual conditions.

The facts presented show some surprising differences and, if their discussion results in a better understanding of the subject, the object of the writer will have been attained.

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CHARLES BENJAMIN BRUSH,

Died June 3, 1897.*

Mr. Brush was born in New York City on February 15, 1848, graduated as Civil Engineer from New York University in 1867, became Adjunct Professor of Civil Engineering in New York University in 1874, Professor in 1888, later becoming Dean of the School of Civil Engineering, and receiving the degree of Doctor of Science in 1892. He was elected a member of the American Society of Civil Engineers in 1877, a Director in 1888, and Vice-President in 1892. He was also a member of the Engineers' Club, the American Water Works Association and the Society for the Promotion of Engineering Education.

He was Chief Engineer of the Hoboken Land and Improvement Company, the North Hudson County Railway Company, the Hoboken Ferry Company, the Hackensack Water Company, the Queens County Water Company and the Portsmouth and Suffolk Water Company. He acted in expert capacity in connection with the bridges at Second and Third Avenue, New York City and over the Thames at New London; also for Chicago and Kansas City in connection with problems of water supply, and for the State of New York in connection with the ceiling of the Capital at Albany. He was at one time engineer for the Hudson River Tunnel Company, also engineer for the contractor during the construction of the famous Washington Bridge over the Harlem, and constructed systems of sewers in North Hudson County, New Jersey, Irvington, New York and many other places. He labored for twenty years to arouse public interest in the building of a boulevard along the Palisades, and was in other ways particularly interested in the development of that section of New Jersey lying opposite New York City.

Mr. Brush was a man of sterling integrity, tireless energy, charitable, broad-minded and of exceptional business ability. He was married in 1883, and a widow and three children survive him.

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* Memoir prepared by Professor C. S. Snow.

ECKLEY BRINTON COXE,

Died May 13, 1895.*

Eckley Brinton Coxe was born in Philadelphia, June 4, 1839, and died at Drifton, Pa., May 13, 1895. In these fifty-six years there was compressed a life of productive activity of remarkable energy and diversity. In the brief space alotted to this memoir, it is impossible to do more than briefly mention his work in promoting engineering education in this country.†

No one was better qualified than Mr. Coxe to advise on the subject of technical education, since he was thoroughly familiar with both its scholastic and its practical side. After graduation at the University of Pennsylvania in 1858, he spent four years at the mining schools of Paris and of Freiberg in Saxony, and subsequently assumed charge of the development of the large coal property in Luzerne Co., Pa., which had been a family possession for generations. He established at Drifton, Pa., in May, 1879, "An Industrial School for Miners and Mechanics" and selected as its first principal Mr. Oswald J. Heinrich. On the latter's death, in 1886, this school was succeeded by "The Mining and Mechanical Institute of the Anthracite Coal Region of Pennsylvania," located at Freeland, Pa.; and, with his characteristic insight into character, Mr. Coxe selected Mr. John R. Wagner, one of his trusted assistants, to organize this enlarged educational enterprise. The successful development of the new school Mr. Coxe gladly ascribed to Mr. Wagner's intelligent management. Mr. Coxe was for many years a trustee of Lehigh University and contributed liberally to its support.

In his numerous occasional addresses on technical education we have an enduring record not only of his great interest in this branch of education, but also of his keen perception of the vital principles which underlie successful training in engineering. These addresses abound with the brilliant, incisive, practical and honest statements so characteristic of the man.

To Mr. Coxe's large circle of friends his strong and winning personality remains a treasured memory equally with his contributions to science and his useful services to his fellow man.

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* Memoir prepared by Dr. T. M. Drown.

† For a full account of his life the reader is referred to a Biographical Notice by Dr. R. W. Raymond, in the Transactions of the American Institute of Mining Engineers, Vol. XXV.

FRANCIS RENATUS FAVA, JR.,

Died March 28, 1896.*

Baron Francis Renatus Fava, Jr., was born in Trieste, Austro-Hungary, in 1860, and after being educated by private tutors he entered the Federal Polytechnic School at Zurich, Switzerland, where he studied engineering and graduated in 1882. He had already shown such marked aptitude as an engineer that he immediately found employment with one of the great iron firms of France, and was entrusted with the building of the iron railroad bridge crossing the Loire at Saumur. Shortly after the completion of this, he went to Hungary, where he was extensively engaged in building railroads and bridges, and he made such rapid progress in his profession that when but twenty-five years of age he was charged with the direction of over 300 men.

In the meantime his father had been commissioned as Envoy Extraordinary and Minister Plenipotentiary from the Kingdom of Italy to the United States Government at Washington and, being their only child, Professor Fava joined his parents in Washington in 1886 and remained their until the time of his death, which occurred in 1896. Soon after taking up his residence in Washington, Professor Fava engaged in architectural work and was actively connected with the building up of several of the Southern towns which at that period were springing up with abnormal activity.

In 1889 he was appointed Professor of Civil Engineering in the Corcoran Scientific School of the Columbian University at Washington, D. C., to succeed Professor Robert S. Woodward, who had just been appointed to the Professorship of Mechanics in Columbia University, New York. Professor Fava brought to these new duties a wide and varied experience and much learning. He was not only a superior mathematician, a skillful draftsman, a clever designer, and an accomplished engineer and architect; but speaking seven different languages with facility, he was a linguist of no mean merit. He thoroughly enjoyed the work of teaching, and was very happy in his methods of presenting the topics he taught. He was unsparing in his labors for the University, and he expected as strenuous exertions from his pupils. He had the gratification of seeing the department under his charge grow steadily in the number of its pupils and in its importance in the University, and in finding that all of those who won the Civil Engineer degree at once secured positions of responsibility in their profession.

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* Memoir prepared by Prof. C. E. Munroe.

JUSTUS MITCHELL SILLIMAN,

Died April 15, 1896.*

Justus Mitchell Silliman was born at New Canaan, Connecticut, January 25, 1842, of a family conspicuous for many years in New England. His father, grandfather and great-grandfather were graduates of Yale. He received his early education in the common schools of New Canaan and in the New Canaan Academy, after which he was retained for several years as an instructor in the latter institution.

At the outbreak of the civil war he enlisted in the 17th Connecticut Volunteer Infantry and served for three years, during which time he took part in the battle of Chancellorsville and Gettysburg, and was wounded, captured and recaptured at Gettysburg. Soon after the battle of Gettysburg, his company was ordered to Charleston, where he took part in the siege of that city. From Charleston he went to Florida, where he remained in service sixteen months.

He entered the Sophomore class of the Rensselaer Polytechnic Institute in September, 1867. During his college course, and for two years previous to his entrance to the Institute, he was an instructor in the Troy Academy.

Professor Silliman took charge of the Department of Mining Engineering at Lafayette College, September, 1870, and continued in that position until his demise, April 15, 1896. He was a Fellow of the American Association for the Advancement of Science from 1870, a member of the American Institute of Mining Engineers from its inception and a member of the Society for the Promotion of Engineering Education since 1894.

Among articles from his pen are papers on the examination of the Bessemer flame with colored glasses and with the spectroscope ; on "Instruments for Orthographic, Clinographic and Crystal Projections," and on "A Water Manometer and Anemometer." He was the author of "Problems in Orthographic Projections," and was about to publish a work on Descriptive Geometry.

Though of a quiet and unassuming disposition, Professor Silliman took great interest in all educational matters and in the students under his care. As an earnest instructor, he spared no pains to make all subjects taught by him interesting and profitable, as well as practical. In the class-room he had the essential characteristics of a thorough teacher and an excellent disciplinarian.

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* Memoir prepared by Professor J. M. Porter.

JAMES HUGH STANWOOD,

Died May 24, 1896.*

James Hugh Stanwood, who became a member of this Society in 1894, was born in Brunswick, Maine, July 17, 1860, and died May 24, 1896, at his home in Boston. Having received his early education in the public schools of Portland, at the age of nineteen he entered the office of Edward C. Jordan, civil engineer, in that city, and for between one and two years was engaged in general land surveying. Afterward he served as assistant in the office of the City Engineer of Portland, and in 1881 became an instrument man with the Maine Central Railroad Company.

When twenty-three years old he entered the Massachusetts Institute of Technology as a student, graduating four years later from the Department of Civil Engineering. During this period he continued his engineering work with the Maine Central railroad through the summer vacations.

Upon graduating, in 1887, Mr. Stanwood went to the Philadelphia Bridge Works as assistant to the designing engineer, but a year or so later returned to the Institute to become Assistant in Civil Engineering. After two years he was promoted to the position of Instructor and continued in active service in that capacity, having charge of the drawing-room work in bridge design, until within a few months of his death. He was forced to give way before the attacks of Bright's disease, and died in his thirty-sixth year, leaving a wife and three children.

He displayed enthusiastic interest in the profession of civil engineering, as well as in his work as a teacher. He found time to make a careful study of the subject of rusting of iron and steel in exposed structures, collecting many interesting specimens to illustrate the matter, and in 1895 participated in the discussion of Mr. J. E. Greiner's paper on the Life of Railroad Bridges, presented before the American Society of Civil Engineers. Simple formulas, which have been well received, were also devised by him to accord with the experiments upon the strength of wooden posts, and were published in the Railroad Gazette in 1892 and 1894.

In intercourse with students, as with all others, Mr. Stanwood was cheerful, courteous and helpful, winning the lasting regard of those who met him, and impressing all as a man of sterling character, conscientious in the performance of every duty.

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* Memoir prepared by Professors Dwight Porter and A. E. Burton.

ALPHONSE N. VAN DAELL,

Died March 28, 1899.*

Alphonse N. Van Daell, Professor of Modern Languages at the Massachusetts Institute of Technology, whose death was recently announced, was a native of Belgium, and was educated at the College of Saint Servais in Liège, from which he graduated in 1864. He subsequently pursued his studies at Louvain, and afterward at the University of Liège, where in 1868 he took the degree of Docteur en Droit. After this, he studied for several years in Paris, Bonn and Berlin.

He came to America in 1873, and taught in private schools until 1876, when he was called to the chair of modern languages in Kentucky College. There he remained for several years, removing in 1879 to Philadelphia, where he again taught for some years in private schools. In 1885, he became Instructor in Haverford College and Lecturer in the University of Pennsylvania, but resigned both these positions in 1886 to accept the office of Director of Modern Languages in the Boston High and Latin Schools. In 1889, he became Professor of Modern Languages at the Massachusetts Institute of Technology, which position he held until his death. He had been in ill health for about a year, and. his condition becoming worse, his physician advised him to seek the treatment at Wiesbaden, Germany. In March last he sailed for Europe, and had just reached his destination when he succumbed to the disease from which he had been suffering. He leaves a widow, a daughter and two sons.

Professor Van Daell was widely known for his writings and for the many text-books which he edited. He was a most agreeable and instructive lecturer, and each year supplemented his work at the Institute by giving courses of lectures in French on literary subjects. He was a man of great learning, and had accumulated a fine collection of valuable editions of literary works in foreign languages. Personally, Professor Van Daell endeared himself to all his friends and to his students by his sincerity, his sympathy and his modesty. He took a great interest in the work of education, and kept in close touch with the preparatory schools, whose needs and whose relations with the higher schools he thoroughly understood from his own experience. He was deeply attached to the Institute, and did much to increase the influence of his own Department in its affairs. His death is a great loss to the Institute, and especially to those who knew him well.

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* Memoir prepared by Professors G. F. Swain and C. F. Allen.

JOHN ROBERT WAGNER,

Died January 21, 1899.*

John Robert Wagner was born in South Bethlehem, Pa., May 12, 1861. His parents were poor, and at the age of nine years he became the sole support of his widowed mother. For several years he earned their joint livelihood as a newsboy and bootblack, with a strong longing for bettering his station in life. He then entered the machinist trade, rising in seven years from the grade of apprentice to that of foreman. During that period he used every means of self-improvement by home-study, and attendance upon night-schools.

He entered Lehigh University at the age of twenty. Upon graduation as mechanical engineer in 1885, he was placed in charge of the extensive scientific library of the late Eckley B. Coxe, at Drifton, Pa. In time he became Mr. Coxe's general scientific assistant, giving special attention to the analysis of coal. Besides expert work in that field, he conducted extensive investigations on the economy of fuel for steam boilers, contributing several articles on that and kindred subjects to engineering journals.

In 1896 he was appointed Superintendent of Motive Power on the Delaware, Susquehanna, and Schuylkill Railroad, and in 1897 he also became Superintendent of Motive Power and Machinery of the Cross Creek Coal Company and the Coxe Iron Manufacturing Company.

His many-sided interest in technical matters is well shown by his membership, at the time of his death, in the American Society of Mechanical Engineers, the American Institute of Mining Engineers, the American Chemical Society, the Society for the Promotion of Engineering Education, and several other organizations.

He was an active worker in philanthropic and educational lines, seeking to help others attain advantages that had come to him only through the greatest sacrifices. In 1886, under the patronage of the late Eckley B. Coxe, he organized at Freeland, Pa., "The Mining and Mechanical Institute of the Anthracite Coal Region of Pennsylvania," for the education of working boys of small means. It was his ambition to eventually carry on such work on a much broader scale.

He was a man of marked ability, strong character, high ideals, and one who evinced a profound sense of the responsibilities of life.

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* Memoir prepared by the Secretary, from information furnished by the family.

FRANCIS AMASA WALKER,

Died January 5, 1897.*

Francis Amasa Walker died suddenly in Boston, January 5, 1897, in his fifty-seventh year. His life was one of remarkably varied activity. His graduation at Amherst was almost immediately followed by distinguished service in the Civil War. At twenty-four he was honorably discharged as brigadier-general, fully equipped as a leader of men.

He was Superintendent of the Ninth and Tenth Censuses from 1870 to 1881, Professor of Political Economy and History in the Sheffield Scientific School from 1873 to 1881. President of the Massachusetts Institute of Technology from 1881 until his death. These are merely the chief of a long list of public services. With all these administrative duties, he was a careful student and a prolific writer on economics.

President Walker found the Institute of Technology just beginning to recover from a period of financial distress, and ready for leadership into larger usefulness. During his administration the number of students and teachers increased nearly four-fold. New courses of instruction were established in Electrical Engineering, Chemical Engineering, Sanitary Engineering, Geology and Naval Architecture, and every one of the older departments gained new strength.

President Walker had been trained in the older classical curriculum, and had experienced much of the antagonism against the newer education. He never ceased to insist on the value of breadth of training to engineering students, and the necessity of literary studies to such breadth. Without specific technical knowledge, he had the best possible acquaintance with the industrial needs and resources of the country. He emphasized always the importance of teaching correct principles as a basis for ultimate professional success, rather than such mere knacks and devices as may give the young graduate a temporary advantage. His personal qualities made him a constant source of strength and inspiration to his associates and students.

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* Memoir prepared by Professor H. W. Tyler.

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